LAKESHORE CAPACITY STUDY
WILDLIFE TECHNICAL REPORT

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TABLE OF CONTENTS

List of Figures iii

List of Tables iv

1. Vegetation Disturbance Caused by Cottage Development in Central Ontario - T. Clarke and D. Euler 1
   - 1.1 Summary
   - 1.2 Introduction
   - 1.3 Study Area
   - 1.4 Methods
   - 1.5 Results and Discussion
   - 1.6 Acknowledgements
   - 1.7 Literature Cited

2. An Index of Habitat Disturbance for Lakeshore Cottage Development - G. Racey and D. Euler 7
   - 2.1 Summary
   - 2.2 Introduction
   - 2.3 Methods
   - 2.4 Results
   - 2.5 Discussion
   - 2.6 Conclusions
   - 2.7 Acknowledgements
   - 2.8 Literature Cited

3. Habitat Associations of Breeding Birds in Cottaged and Uncottaged Areas of Central Ontario - K. Clark, D. Euler and E. Armstrong 11
   - 3.1 Summary
   - 3.2 Introduction
   - 3.3 Study Area
   - 3.4 Methods
   - 3.5 Results
     - 3.5.1 Principal Analysis
     - 3.5.2 Discriminant Function Analysis
   - 3.6 Discussion
   - 3.7 Acknowledgements
   - 3.8 Literature Cited

4. The Impact of Cottage Development on Common Loon Reproductive Success in Central Ontario - M. Heimberger, D. Euler and J. Barr 19
   - 4.1 Summary
   - 4.2 Introduction
   - 4.3 Study Area and Methods
   - 4.4 Results
   - 4.5 Discussion
   - 4.6 Acknowledgements
   - 4.7 Literature Cited
   - Appendix I
   - Appendix II

5. Habitat Selection Within Four Passerine Families in Central Ontario - E. Armstrong, D. Euler and K. Clark 27
   - 5.1 Summary
   - 5.2 Introduction
   - 5.3 Study Area
   - 5.4 Methods
   - 5.5 Results
   - 5.6 Discussion
   - 5.7 Acknowledgements
   - 5.8 Literature Cited

6. Reproductive Ecology and Habitat Usage of Woodland Buteos in Central Ontario - E. Armstrong and D. Euler 35
   - 6.1 Summary
   - 6.2 Introduction
   - 6.3 Study Area and Methods
   - 6.4 Results
     - 6.4.1 Nesting Chronolog
     - 6.4.2 Habitat Characteristics
     - 6.4.3 Nesting Success
     - 6.4.4 Raptor Observations
     - 6.4.5 Behavioural Interactions
   - 6.5 Discussion
   - 6.6 Acknowledgements
   - 6.7 Literature Cited

7. Predicting Avian Community Response to Lakeshore Cottage Development - K. Clark, D. Euler and E. Armstrong 43
   - 7.1 Summary
   - 7.2 Introduction
   - 7.3 Methods
   - 7.4 Results
   - 7.5 Discussion
   - 7.6 Acknowledgements
   - 7.7 Literature Cited

8. Changes in Mink Habitat and Food Selection as Influenced by Cottage Development in Central Ontario - G. Racey and D. Euler 51
   - 8.1 Summary
   - 8.2 Introduction
   - 8.3 Methods
     - 8.3.1 Study Area
     - 8.3.2 Vegetation Analysis
     - 8.3.3 Dens
     - 8.3.4 Shorewalking
     - 8.3.5 Indices
   - 8.4 Results and Discussion
     - 8.4.1 Vegetation Analysis
     - 8.4.2 Dens
     - 8.4.3 Shorewalking
     - 8.4.4 Food Habits
   - 8.5 Acknowledgements
   - 8.6 Literature Cited

9. Small Mammal and Habitat Response to Shoreline Cottage Development in Central Ontario - G. Racey and D. Euler 62
9.1 Summary
9.2 Introduction
9.3 Methods
9.4 Results
9.5 Discussion
9.5.1 Vegetation
9.5.2 Masked Shrew
9.5.3 Short-tailed Shrew
9.5.4 Eastern Chipmunk
9.5.5 Red Squirrel
9.5.6 Deer Mouse
9.5.7 Red-backed Vole
9.5.8 Woodland Jumping Mouse
9.5.9 Species Relationships and Habitat Change
9.6 Acknowledgements
9.7 Literature Cited

10. Deer Habitat Quality and Influences of Cottage Development in Central Ontario - E. Armstrong, D. Euler and G. Racey 75
10.1 Summary
10.2 Introduction
10.3 Study Area
10.4 Materials and Methods
10.5 Results
10.6 Discussion
10.7 Literature Cited

11. Reptile and Amphibian Habitat and Human Activity in Central Ontario - K. Clark and D. Euler 81
11.1 Summary
11.2 Introduction
11.3 Methods
11.4 Results and Discussion
11.4.1 Spotted Salamanders
11.4.2 Spring Peepers
11.4.3 Turtles
11.5 Acknowledgements
11.6 Literature Cited

12. The Importance of pH and Habitat Disturbance in Amphibian Distribution in Central Ontario - K. Clark and D. Euler 91
12.1 Summary
12.2 Introduction
12.3 Methods
12.4 Results
12.5 Discussion
12.6 Conclusions
12.7 Literature Cited

LIST OF FIGURES

1.1 The central Ontario area.
1.2 Schematic representation of a cottage lot showing the typical pattern of disturbance of ground, shrub and tree strata.
2.1 Map of the study area.
2.2 A schematic representation of disturbance in the three layers of vegetation.
2.3 Frequency distribution of lot sizes in the study area.
2.4 Relationship between the area development index (ADI) and the area of the cottage lot (AREA).
3.1 The study area.
3.2 Representation of the first three axes of the habitat ordination of bird species' singing posts.
3.3 Representation of the first three axes of the habitat ordination of bird species' nest sites.
3.4 Ordination of bird species' singing posts.
3.5 Ordination of bird species' nest sites.
4.1 Map of the study area.
4.2 Habitat analysis plot for actual loon nests and possible nesting sites.
4.3 Date of initiation of incubation.
4.4 Percent of breeding pairs of loons versus development.
4.5 Discriminant function axis with successful and unsuccessful loon nests.
4.6 Discriminant function axis with actual and possible loon nesting sites.
5.1 Two dimensional ordination of flycatcher habitat.
5.2 Two dimensional ordination of thrush habitat.
5.3 Two dimensional ordination of warbler habitat.
5.4 Two dimensional ordination of finch habitat.
5.5 Relative frequency of observation of woodland birds in 4 vegetative types.
5.6 Relationship between percent coniferous composition of warbler habitat and coniferous tree usage.
6.1 The study area.
6.2 Temporal trends in observed nesting activities of Broad-Winged and Red-Shouldered Hawks.
7.1 The study area.
7.2 Linear regressions between habitat characteristics and the GDI for deciduous and coniferous plots.
7.3 Occurrence of bird species at varying levels of development (GDI) in coniferous habitats.
7.4 Likelihood of occurrence of bird species at varying levels of development (GDI) in deciduous habitats.
7.5 Linear regressions between the coefficient of community and the GDI in deciduous and coniferous plots.
7.6 Linear regressions between the number of breeding bird species and GDI in deciduous plots.
7.7 The relationship between GDI and the number of cottage clearings per ha.
8.1 Map of the study area in central Ontario.
8.2 Three dimensional illustration of mink use patterns with respect to coniferous composition of habitat and level of development.
8.3 Frequency histogram of the number of mink scats.
8.4 Relationship between relative mink activity and cottage loading development index.
8.5 Linear response surface of the mink activity factor to the development index and the coniferous composition.
8.6 Relationship between mink activity and the intensity of cottage development.
8.7 Percentage of scats containing each food item.
8.8 Variations in the occurrence of food items in scats with respect to habitat type and levels of development.
9.1 Map of study area (Muskoka-Haliburton).
9.2 Schematic diagram of a plot on which small mammals were captured.
9.3 Plot of the capture index of each species studied versus three levels of the development index.
9.4 Three dimensional representations of mammal captures.
9.5 Separation of small mammal species.
10.1 A 2-dimensional ordination of the functional habitat types of deer concentration areas based on the DFA.
10.2 A 2-dimensional ordination of sheltered shoreline areas and cottaged coniferous areas of a deer concentration area based on the DFA.
10.3 A diagrammatic representation of the relationships of deer habitat components and developed shoreline areas.
11.1 Linear regression of number of egg masses and GDI.
11.2 Linear regressions of habitat characteristics and GDI.
11.3 Linear regressions of pH and GDI.
11.4 Linear regressions of habitat characteristics and GDI.
11.5 Linear decision scale for spring peeper male calling sites.
11.6 Linear regressions of habitat characteristics and GDI.
11.7 Linear regressions between the density of calling spring peeper males and mean pH.
11.8 Linear decision scale for turtle breeding sites.
11.9 Linear regressions of habitat characteristics and GDI.
12.1 The mean discriminant function score of each species.

LIST OF TABLES

1.1 Vegetation variables used for comparison with the GDI.
1.2 Results of PCA of selected vegetation variables.
1.3 Results of stepwise DFA of vegetation parameters.
1.4 Results of stepwise DFA of selected vegetation variables.
2.1 Variable names and definitions.
2.2 Mean area disturbed and standard error for each of the lot size classes.
3.1 Vegetation variables for analysis of nest sites and singing posts.
3.2 Species and sample sizes.
3.3 Results of the PCA of 22 vegetation variables for 16 breeding bird species' singing posts.
3.4 Results of the PCA of 22 vegetation variables for 12 bird species singing posts.
3.5 Standardized discriminant function coefficients for the first 3 discriminant functions for 15 species' singing posts.
3.6 Comparison of PCA results with published studies.
4.1 Summary of common loon reproductive success (1977-1979).
4.2 Distance from cottage(s) to common loon nests.
4.3 Cottage density and common loon nesting sites.
4.4 Occupied loon territories with nests.
4.5 Comparison of weighted cottage activity within 150 m of developed and undeveloped common loon nests.
4.6 PCA of successful and unsuccessful common loon nests.
4.7 PCA of actual and potential common loon nests.
5.1 Passerine families and species studies.
5.2 Habitat variables.
5.3 Matrix of F values for separation of each species centroid.
6.1 Microhabitat characteristics of Broad-Winged and Red-Shouldered Hawks.
6.2 Microhabitat characteristics of Broad-Winged and Red-Shouldered Hawks.
6.3 Nest tree species used by Broad-Winged and Red-Shouldered Hawks.
6.4 Location and behaviour observations for Broad-Winged and Red-Shouldered Hawks, 1978-1979.
7.1 Correlation coefficients for the association between disturbances and habitat variables.
7.2 Number of deciduous plots on which a species was present for two sets of intervals of the ground development index (GDI).
7.3 Number of coniferous plots on which a species was present for two sets of the GDI.
8.1 Definitions of variables measured on vegetation subplots.
8.2 Definitions of variables measured on aquatic portions.
8.3 Definitions and univariate statistics of variables measured in the area surrounding mink dens.
8.4 Observed and expected number of scats found in each category of coniferous composition and development.
8.5 Results of mink food habits analysis compared to that of Hamilton (1959).
9.1 Functional vegetation groups and significant correlations with the development index (DI) on shoreline plots.
9.2 Results of PCA on vegetation and development measures and small mammal species.
9.3 Prediction equations for animal captures versus the DI.
9.4 Prediction equation of relative animal populations.
10.1 Summary statistics for functional habitat types in central Ontario deer concentration areas.
10.2 Results of the principal component analysis (PCA) of habitat variables in deer concentration areas.
10.3 Results of the discriminant function analysis (DFA) for functional habitat types in deer concentration areas.
10.4 Summary statistics for sheltered shoreline areas and cottaged coniferous areas in deer concentration areas.
10.5 Results of DFA for sheltered shoreline areas and cottaged coniferous areas in deer concentration areas.
11.1 Correlation coefficients for density of egg masses, QUADG, and habitat variables.
12.1 Mean and range of habitat characteristics for amphibian species locations.
12.2 Mean and range of water chemistry variables for amphibian species locations.
12.3 Mean density per census of amphibian species.
12.4 Summary statistics for DFA of habitat characteristics near amphibian sitings.
12.5 Sorted rotated factor loadings for the PCA of amphibian densities and habitat characteristics in ponds.
12.6 Sorted rotated factor loadings for the PCA of amphibian densities and areas of vegetation types in ponds.
12.8 Sorted rotated factor loadings for the PCA of amphibian densities and areas of vegetation types in streams.
12.9 Sorted rotated factor loadings for the PCA of amphibian densities and water chemistry in ponds.
12.10 Sorted rotated factor loadings for the PCA of amphibian densities and water chemistry in streams.

1. VEGETATION DISTURBANCE CAUSED BY COTTAGE DEVELOPMENT IN CENTRAL ONTARIO

T. CLARK and D. EULER

1.1 SUMMARY

Changes in vegetation following lakeshore cottage development in central Ontario were studied using a disturbance index. Principal Component Analysis and Discriminant Function Analysis were used to describe the variables which comprise the index. Four key variables had a close relationship with cottage development: number of snags, number of shrub snags, ground volume of vegetation and frequency of raspberry. On average cottage development changes vegetation patterns in predictable ways which are useful in understanding the impacts of human activity on the undeveloped plant and animal communities.

1.2 INTRODUCTION

Cottage development on lakes in central Ontario has had a serious impact on shoreline vegetation. This, in turn, affects wildlife and may alter other aspects of the ecosystem. It is important to know how this disturbance changes the vegetation in order to understand the overall impact on the ecosystem.

Amiro and Courtin (1981), working in Sudbury, Ont., found that an index was the most practical means of dealing with a disturbed environment in a region with a wide range of vegetation types. Racey and Euler (1981) approached this problem, using a simple disturbance index, the Area Development Index (ADI), which is based on the area of vegetation cleared for a cottage. This index was found to be useful in predicting changes to wildlife habitat. However, the ADI does not deal with individual species or broader variables such as change in tree species composition which are important for understanding the mechanism of change. The purpose of this paper is to describe the variables of this index and examine how cottage development changes vegetation along lakeshores.

1.3 STUDY AREA

The study was conducted in the Muskoka and Haliburton Regions of central Ontario (Fig. 1.1). This area is characterized by rolling forested hills with many lakes and rivers, rock outcrops, and a thin layer of glacial till over bedrock. It is located on the Precambrian Shield in the Georgian Bay section of the Great Lakes Forest Region (Rowe 1972). It is an ecotonal area between the Boreal and Deciduous forests, showing the elements of both. Rowe (1972) lists the most important trees of the area as sugar maple *(Acer saccharum)*, American beech *(Fagus grandifolia)*, basswood *(Tilia americana)*, hemlock *(Tsuga canadensis)*, yellow birch *(Betula lutea)*, white pine *(Pinus strobus)*, and red maple *(Acer rubrum)* which form mixed stands in upland areas. The Boreal component is shown by the presence of balsam fir *(Abies balsamea)* and white spruce *(Picea glauca)* at higher altitudes. In southern and western areas of this region, extensive swamp stands of red maple, black ash *(Fraxinus nigra)* and eastern white cedar *(Thuja occidentalis)* occur.

Figure 1.1 The central Ontario study area from which 24 lakes were selected.

1.4 METHODS

Twenty-four lakes of moderate size (70-200 ha), within a 50 km radius of Dorset, Ontario were selected. Study plots were chosen on shores with moderate slope (less than 20%) to the water-land interface and with a reasonable soil deposition (not rock or sand). In the interests of obtaining sites throughout the Dorset area which is a typical cottage area, more rigid requirements could not be imposed. The only factor intentionally varied was the density of cottage development. This ranged from none to the highest observed density of

cottages. The plots without cottages were considered undisturbed.

Vegetation was sampled on 55 plots each consisting of two 20 x 50 m (0.1 ha) quadrats following the methods of Whittaker (1973 p. 10-11). One of these quadrats was parallel and adjacent to the lakeshore; the other was perpendicular to and adjoined the first quadrat, thereby forming a "T" shape.

Within each plot all trees (>9.0 m height) and shrubs (between 1.5 m and 9 m) were identified and counted. The diameter at breast height (dbh) was recorded for trees. Tree and shrub cover and volume of foliage were estimated using a modification of the range finder method (Anderson and Shugart 1970) on 50 1-m^2 subquadrats randomly placed in the T-plot. Tree and shrub snags were also counted; these are dead stems and branches of importance to wildlife, particularly to birds which use them as perching and nesting sites.

The ground stratum (<1.5 m height) was measured in the 50 subquadrats. Species and number of individuals were recorded along with cover and volume of the ground layer foliage. The frequency of occurrence of each species was calculated from these data. Totals for the 25 subquadrats were used in the analysis.

The ADI was based on area disturbance of vegetation in three layers, ground, shrub, and tree (Racey and Euler 1981). This disturbance was measured in a 50 x 50 m (0.25 ha) block overlying the plot. This block was larger than the vegetation plot because measuring disturbance caused by cottage development required a size larger than most cottage lots. The index was calculated as follows:

$$ADI = (Ag + As + At)/AREA \quad (1)$$

where Ag = the area disturbed in the ground layer.
As = the area disturbed in the shrub layer.
At = the area disturbed in the tree layer.
AREA = 0.25 ha

An area was considered disturbed if a building or other man-made object occupied it, or if human activity had halted natural succession or returned the area to an earlier successional stage. The ADI ranged in value from 0.0 to 3.0. When the vegetation of a sample plot was entirely disturbed, the ADI had a value of 3.0. Disturbance or ADI values between 0.0 and 3.0 were generally easy to quantify because these sites were previously well treed and characteristic of Great Lakes St. Lawrence Forest. The signs of cottage disturbance form a clear pattern within this "uniform" natural setting, very much like Figure 1.2. It is not necessary to identify species as an aid to judging disturbance. Other disturbances associated with cottages, such as roadways and hydro clearings, are also readily identified.

A component of the ADI, the Ground Development Index (GDI), was also used in the analysis.

$$GDI = Ag/AREA \quad (2)$$

where Ag and AREA are defined as in Eq. 1.

Correlations, Principal Component Analysis (PCA), and stepwise Discriminant Function Analysis (DFA) were computed, using the Biomedical Computer programs (Dixon 1975). PCA and DFA were done for each of the three vegetation strata and for the general variables such as tree and shrub number. Based on these analyses important variables from all three strata were used for a final PCA and DFA. Only the first three components of the PCA are reported here. For the DFA, an F-to-include value of 4.0 was used with the classification procedure in which posterior probabilities were proportional to group size. Basically the F-to-include refers to a measure of variance as measured by an F value (Snedecor and Cochrane 1963), which is attributable to a difference between groups, and therefore is a good indicator of an important discriminating variable.

Only species which occurred frequently were recorded, because rare or locally important species would be unlikely to provide information useful in characterizing the effects of cottage development. Nomenclature follows Fernald (1950).

1.5 RESULTS AND DISCUSSION

The ADI has proven to be a useful index for measuring the impact of cottage development on wildlife, particularly birds (Clark et al. 1981) and small mammals (Racey and Euler 1982). The difficulty with an index, such as ADI, is that it represents a large number of variables which may be of scientific importance by themselves (Pielou 1967). This loss of information is necessary if a management problem can be more readily dealt with and understood, without unnecessary complications (Holling 1978) such as numerous variables. Hopkins (1977) refers to this as a "gestalt" method in which an ecosystem is not conceptually divided into its components.

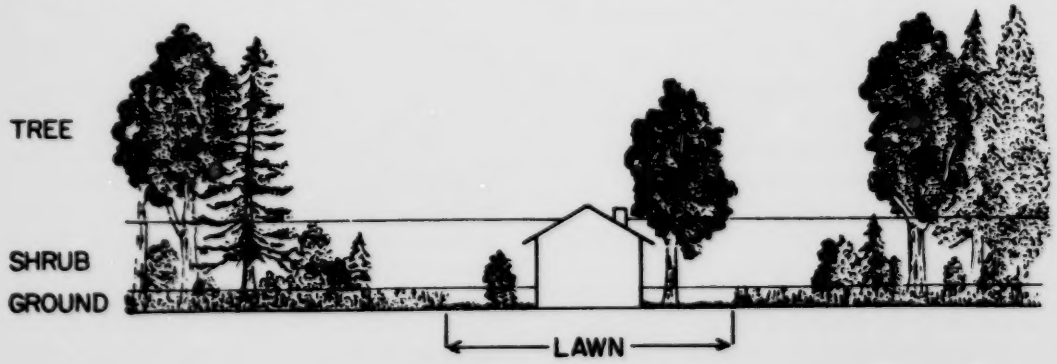

Figure 1.2 Schematic representation of a cottage lot showing the typical pattern of disturbance of ground, shrub and tree strata.

The ADI is an attempt to reduce the complexity of a highly variable situation. Amiro and Courtin (1981) used an analogous index for dealing with vegetation damage caused by industrial SO_2 emissions in the Sudbury Ontario region.

The present use of ADI in management situations (Teleki and Herskowitz 1982) made a better understanding of the underlying characteristics of the index desirable. It was not the intent of this paper to prove the hypothesis that ADI measures vegetational change. Clearly, ADI was a function of the abundance of numerous plant species and cannot be used subsequently to prove that vegetation is impacted by development as measured by the ADI. Rather the intention was to describe the important components of the index to provide a clearer understanding of its underlying mechanism. In addition, variables emerged which have a scientific value of their own.

Twenty-eight vegetation variables, covering a broad spectrum of the vegetative community, were significantly ($p<0.05$) correlated with values of the GDI (Table 1.1). The large number of negative correlations between the species variables and GDI is a function of the type of variables selected. This correlation cannot be taken by itself as an indication of an overall decline in the amount of vegetation in cottaged areas. For example, it does not rule out the possibility that native lakeshore species are replaced by domesticated species or early succession species which typically follow human habitation. Notably, few native species examined had a positive correlation with GDI.

Negative correlation with general variables such as tree individuals, tree and shrub cover, and volume is expected because of the nature of ADI and GDI (Table 1.1). The general variables are the most closely related to the indices. In turn, these general variables are comprised of variables describing individual species.

The PCA of tree stratum variables organized the variables into three important groups. The first, explaining the most variance, 23.2%, corresponded to the degree of development of lakeshores. It was clear that development was the primary course of this component because it had a strong negative correlation with GDI (−0.733). Positive correlates included three general variables: tree cover, tree volume and number of trees. As cottages are built there is a reduction in the number of trees. A modified tree stratum breaks the natural continuity of the forest, and is the basis for disturbances in the shrub and herb strata. The second and third groups of the PCA were produced by variables associated with coniferous and deciduous composition respectively. These simply reflect the natural variation in a forest canopy; many forest characteristics are represented by a few variables. The PCA groups these characteristics into major sources of variation. In this case disturbance related variables cause most of the variance. The coniferous and deciduous elements were less important than the man-made disturbance factor.

The first factor of the shrub stratum PCA was comprised of deciduous characteristics not related to development which included number of beaked hazel and black cherry and number of deciduous shrubs. The second axis represents the development variables. The GDI was negatively correlated and snags were positively correlated with this axis, and, therefore, appear to have an inverse relationship. This indicated that snags are removed from the lakeshore environment by cottagers who probably feel that dead plants do not belong in their living area. At the same time, they may disregard other living shrubs which they would not consider attractive in an urban environment. Conifer variables, which included number of balsam fir, and spruce, were associated with the third axis of the PCA.

In the ground layer analysis, GDI was positively correlated with the second component explaining 17.2% of the variability. This variable showed development was the significant factor along this axis. Dandelion and hawkweed were also positively correlated with this axis and demonstrated the effect of land clearing, since these and other well-adapted non-native species quickly fill available niches resulting from development. Numerous species invade the disturbed area, and many complex associations arise between indigenous and

Table 1.1 Vegetation variables used for comparison to the Development Index (GDI)

Tree Variables	Shrub Variables	Ground Variables
No. tree species	No. shrub species	No. ground stratum species
No. tree individuals*	No. shrub individuals*	No. ground stratum individuals
Tree cover*	Shrub cover*	Ground Cover
Tree volume*	No. conifer shrubs*	Ground volume*
No. coniferous trees*	No. deciduous shrubs*	No. bunchberry *(Cornus canadensis)*
No. deciduous trees*	No. shrub snags*	Frequency of bunchberry
Percent conifer composition*	No. speckled alder *(Alnus rugosa)*	No. dandelion *(Taraxacum officinale)***
Percent conifer volume*	No. raspberry *(Rubus* sp.*)*	Frequency of dandelion**
No. hemlock *(Tsuga canadensis)**	No. balsam fir *(Abies balsamea)**	No. woodfern *(Dryopteris* spp.*)*
No. sugar maple *(Acer saccharum)*	No. black cherry *(Prunus serotina)**	Frequency of woodfern*
No. red maple *(Acer rubrum)*	No. cedar *(Thuja occidentalis)*	No. goldthread *(Coptis groenlandica)**
No. white birch *(Betula)*	No. beaked hazel *(Corylus cornuta)**	Frequency of goldthread*
No. yellow brich *(Betula lutea)**	No. hobblebush *(Viburnum alnifolium)*	No. raspberry *(Rubus* sp.*)***
No. white pine *(Pinus strobus)*	No. winterberry holly *(Ilex verticillata)*	Frequency of raspberry**
No. red oak *(Quercus rubra)*	No. juneberry *(Amelanchier* sp.*)*	No. wood sorrel *(Oxalis montana)*
No. snags (trees and shrubs)*	No. mountain maple *(Acer spicatum)*	Frequency of wood sorrel
	No. spruce *(Picea* sp.*)*	No. hawkweed *(Hieracium** spp.*)*
	No. viburnum *(Viburnum* sp.*)*	

*Negatively correlated with GDI ($p<0.05$, $n=55$)
**Positively correlated with GDI ($p<0.05$, $n=55$)

introduced species. The first axis of the PCA was comprised of species typical of dark, moist, coniferous areas. General vegetation parameters, including cover and volume, were associated with disturbance on the third component axis.

A final PCA was done, using the general descriptive measurements such as cover and volume which applied to all species of a stratum (Table 1.2). This increased the number of variables which contributed a significant variance to the first two axes, but as in the PCA of the shrub and ground strata, development was described by the second axis. The analysis was intended to give a broader perspective to the view of impact on vegetation, and to indicate on a macro scale if vegetation structure had been affected. Clearly, the number of variables on the second and third axes indicated that, even on a broad scale, changes occur in the vegetation in all three strata.

Table 1.2 Results of the Principal Component Analysis of selected vegetation variables from the tree, shrub and ground strata.

	Component		
	1 (25.3)*	2 (44.6)	3 (60.5)
Habitat Variables			
No. of Shrub Species	0.820**	0.0	0.0
Conifer Composition (%)	-0.808	0.0	0.0
No. Ground Species	0.741	0.0	0.0
No. Conifer Trees	-0.738	0.0	0.0
No. Deciduous Trees	0.675	0.478	0.358
Ground Volume	0.646	0.607	0.0
Tree Cover	0.0	0.834	0.0
GDI	0.0	-0.701	-0.308
No. Black Cherry Shrubs	0.323	0.657	0.0
Frequency Raspberry	0.264	-0.560	0.0
No. Shrub Snags	0.0	0.0	0.973
No. Snags	0.0	0.0	0.947
No. Conifer Shrubs	0.0	0.0	0.0
No. Wood Sorrel	0.0	0.0	0.0
Explanations	Moisture gradient	Disturbance related	Disturbance related

*Cumulative proportion of variance explained
**Correlations to original variables

Note: This table is arranged so that columns appear in decreasing order of variance explained by factors. The rows have been arranged so that factor loadings (correlations) greater than 0.5 appear first and loadings less than 0.25 were replaced by 0.

A stepwise DFA was used to objectively select vegetation variables important in describing the GDI. The plants and other variables selected by the DFA are those which closely parallel changes in the environment, for example plants which commonly invade a disturbed area, or are quickly altered or extirpated by cottagers. Note that these variables are intended for use as a gauge of the GDI, and are neither the only variables affected nor the most affected.

The form of the discriminant function equation is:

$$Y = m_1X_1 + m_2X_2 + \ldots m_nX_n + C \qquad (3)$$

where Y = the approximate level of development (dimensionless).
X = measured values of the vegetation variables.
m = coefficients of the discriminant functions (weighting).
C = DFA constant.

In the tree stratum, 2 variables, describing tree cover and tree individuals, were selected. Therefore, in the case of the tree stratum, the equation would be as follows:

$$Y = 0.0135 \text{ (No. of deciduous trees)} + 0.0449 \text{ (Tree cover)} + (-3.5779) \qquad (4)$$

The mean values for the two variables if substituted into the equation, give expected values of Y. For undeveloped sites, the Y value was 1.12 and for developed sites, it was −0.59. These values would be of use in examining the influences of cottage development if they were calibrated with GDI.

In the shrub stratum two of the selected variables, total snags, and shrub snags were related, but their contribution to the DFA (Coefficients 0.05 and −0.03 respectively) indicates they had a different source of variation. The total snags variable includes tree size individuals which probably accounts for this difference. As with trees, cottagers arrange the shrubby vegetation according to concepts based on urban values. Black cherry shrubs, common in this area, were also selected by the DFA. Although these flowering bushes are very attractive, well-foliated and probably favoured by knowledgeable individuals, the overall impulse of cottagers is to remove this species.

Not unexpectedly, in the ground stratum ground volume was chosen as a good discriminating variable for the GDI, since they are closely related measures. The frequency of raspberry actually had a higher coefficient, indicating it had a higher weighting, and was more important in the discrimination procedure. Its occurrence in openings shows an ability to quickly colonize disturbed areas. Its selection by the DFA as an indicator shows that cottage development improves its habitat, and that it is a good gauge of GDI.

The general vegetation parameters were also analysed, using DFA in order to obtain a different perspective (Table 1.3). The results were very similar to previous DFA, except that conifer shrubs and conifer composition were also selected. It is possible that these variables were selected by the DFA because cottagers tend to decrease the amount of conifer by eliminating coniferous shrubs in favour of deciduous ones. Furthermore, it can be seen that cottagers prefer white birch rather than conifer species.

Table 1.3 reports a "success rate" of the DFA which refers to back checking the equations with the data used in the DFA. A high success rate is expected because ADI is closely related to the variables used in the DFA.

Finally, in order to obtain a short list of key habitat disturbance indicators, a DFA was done on all variables selected in the first four DFA procedures. This successfully classified 92.7% of the sampled plots (Table 1.4) using only four variables: number of snags, number of shrub snags, ground volumes and frequency of raspberry. The number of shrub species had the highest weighting, indicating a very close relation between development and this variable. This is probably caused not only by cottagers removing native shrub species, but also by replacing them with exotic types. Raspberry is the only species variable selected in the final group of discrimination variables. This is, therefore, a key variable for the assessment of the level of development. The reasons for the selection of both snags and ground volume have been previously discussed.

We believe the use of the ADI provides a means for mitigating impact of cottage development on vegetation. Racey and Euler

(1981) reported that the disturbance caused by one cottage tends to be constant (0.1333 ha) regardless of the size of the cottage lot. This leads to a means of mitigating damage by simply increasing the minimum allowable lot size before a cottage subdivision receives approval. An alternative, however, is to leave large undisturbed areas on each lake. This has the advantage of benefitting rare species which would probably have a better chance of survival in areas where there is little human interference.

Another alternative to these would be a system of development classifications. Some cottagers have no desire for lawns, running water, and beaches, for example, and for them certain lakes could be designated as natural areas. On these lakes, cottage lots could be small with large stretches of publicly owned, undisturbed land between them.

The ADI or GDI has the capability to develop into an important component of a vegetation analysis methodology such as that proposed by Howell (1981). That author stated that vegetation analysis systems are primitive in comparison to systems for evaluating other resources such as soil. It is essential that systems for evaluating vegetation be improved if planners and land managers are to be able to incorporate this resource into land-use plans.

Table 1.3 The results of the stepwise Discriminant Function Analysis of vegetation parameters for discriminating between developed and undeveloped sites.

	No. Shrub Species	% Conifer Composition	No. Snags	No. Conifer Shrubs	Ground Volume	GDI *	% Classified Correctly by DFA**	Mean Values of Canonical Variables
Means and Standard Deviations								
Undeveloped Group (n=19)	10.0 (±3.6)	43.4 (±32.2)	86.5 (±65.3)	194.7 (±157.5)	20.8 (±10.4)	0.0 (±0.0)	94.7	2.25
Developed Group (n=36)	10.6 (±4.1)	48.0 (±30.3)	21.8 (±20.3)	96.6 (±63.3)	12.1 (±5.3)	.91 (±.63)	97.2	−1.19
Combined (n=55)	10.4 (±3.9)	46.4 (±31.0)	44.2 (±41.5)	130.5 (±105.2)	15.1 (±7.4)	.60 (±.52)	96.4	
Canonical Coefficients of the Discriminant Function#	−0.2526	−0.0173	0.0143	0.0047	.0966	−0.0001		

* GDI is the development index, therefore the mean value for the undeveloped group = 0
\# Discriminant function constant = 1.357
**Using posterior probabilities

Table 1.4 The results of the stepwise Discriminant Function Analysis of selected vegetation variables for discriminating between developed and undeveloped sites.

	No.Snags	No. Shrub Snags	Ground Volume	Frequency Raspberry	% Classified Correctly by DFA**	Mean Values of Canonical Variables
Means and Standard Deviations						
Undeveloped Group (n=19)	86.5 (±65.3)	10.0 (±3.6)	20.8 (±10.4)	0.80 (±1.5)	94.7	2.04
Developed Group (n=36)	21.8 (±20.3)	10.6 (±4.1)	12.1 (±5.3)	4.4 (±3.6)	91.7	−1.08
Combined (n=55)	44.2 (±41.5)	10.4 (±3.9)	15.1 (±7.4)	3.2 (±3.1)	92.7	
Canonical Coefficients of the Discriminant Function #	0.0188	−0.1653	0.1412	−0.1597		

\# Discriminant function constant = −0.75
**Using posterior probabilities

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2. AN INDEX OF HABITAT DISTURBANCE FOR LAKESHORE COTTAGE DEVELOPMENT

G. RACEY and D. EULER

2.1 SUMMARY

Quantification is an important aspect of the environmental impact assessment process. This paper describes an index of habitat disturbance and discusses its use and applications. Characteristics of cottage lots in central Ontario are also discussed.

Cottage lots in this study area belong to a highly skewed distribution with a mean of 3,789 m^2 and a mode of 2,500 m^2. The amount of habitat disturbance around cottages was independent of lot size and appeared to vary primarily with preferences of individual cottagers. The ground, shrub, and tree layers of the vegetation were affected by development to differing degrees. The Area Development Index, derived from lot size, proved to be a useful indicator of habitat disturbance.

2.2 INTRODUCTION

In recent years, concern has been raised about the economic and ecological impact of cottage development in rural Ontario (Graham 1967). The areas most affected are lakeshores and waterways on which 83% of Ontario cottages are located (Ontario 1968). It is quite evident that shoreline development directly alters vegetation through road, powerline and building construction as well as maintenance activities such as the clearing of trees and shrubs. The extent to which these activities occur depends on many socio-economic variables and aesthetic values (Graham 1967; Buhyoff et al. 1978; Sargent and Zayac 1977). The biological impact of development includes the alteration of environmentally sensitive areas, destruction of aquatic and terrestrial wildlife habitat and nutrient imbalance in lakes. The aesthetic value of the landscape is also altered by the presence of man-made structures and clearings (Moroz 1976; Abelson 1979) and by alterations made to the vegetation (Klukas and Dunson 1967; Radar and Hamilton 1974).

Environmental impact studies frequently encounter difficulty in quantification and the use of standard statistical methods (Bissett 1978) as well as in the use of irrelevant economic variables. Eberharst (1976) notes the importance of quantification in solving the problems associated with the application of classical inferential methods used to compare pre- and post-operational data. Cost benefit analysis is used, sometimes incorrectly, to interpret aesthetic and social values according to the results of commercial analysis (Price 1977). Therefore, when attempting to assess the impact of cottage development, some common, quantifiable expression of development is required.

Knetsch and Freeman (1979) have divided an environmental assessment into three stages, identification, measurement, and evaluation, but suggest that only the first two are accomplished to any degree in most environmental studies. Dooley (1979) stressed the importance of identifying and measuring impacts on four scales, temporal, societal, spatial and risk. The spatial scale is most important to the assessment of cottage development impacts on habitat.

Comprehensive evaluation of development impact on any of these scales requires that development be quantified on some continuous scale to minimize the problems discussed by Eberhardt (1976). This can be done, using a development index.

Indexing of land use characteristics over large areas has been accomplished by Sargent and Zayac (1977). They created a land use index for planning in basins. This index was based on seven land use characteristics, which include lot size and proximity to roads. This index indicated the degree to which various land use patterns contributed to cultural and biological change.

The main purpose of this paper is to identify a useful index, which can be used to quantify habitat changes resulting from lakeshore cottage development. A secondary purpose is to provide additional information on some characteristics of cottage lots in central Ontario.

2.3 METHODS

During the summer of 1979, 32 developed lakes were chosen at random in a 4,000 km^2 area in the Muskoka-Haliburton area of central Ontario (Fig. 2.1). Lot size was calculated from development plan maps for 1,036 lots. Adjacent cottage lots owned by the same person were treated as a single lot, and assigned to a size class equal to the total of the two. A sample of 150 lots was used for detailed measurements, 15 from each size class.

For each cottage lot in the sample, values for eight variables were recorded (Table 2.1). AREA and TLEN were obtained from the development plan maps. BUILD, ABUILD and WATER were measured during a visit to the lot. The remaining variables, Ag, As, and At were estimated from the existing vegetation on the cottage lot. Vegetation was classified as part of the ground (herbaceous vegetation and seedlings), shrub (woody plants less than 8.0 cm dbh), or tree (woody plants greater than or equal to 8.0 cm dbh) layers.

Figure 2.1 Map of the study area.

A section of vegetation layer was considered disturbed if a building or other man-made object occupied it, or if human activity had halted natural succession and/or returned and maintained the area at an earlier successional stage.

An Area Development Index (ADI) was calculated from the variables (Table 2.2) by the following formula:

$$ADI = (Ag + As + At)/AREA \quad (1)$$

Where Ag = area disturbed in ground layer
As = area disturbed in shrub layer
At = area disturbed in tree layer

When the lot was entirely disturbed, the ADI had a value of 3.0.

The variables required to calculate the ADI were measured in the field by carefully pacing the dimensions of cleared or disturbed areas. A schematic diagram of a developed lot is given in Figure 2.2.

A configuration coefficient was calculated from the recorded variables:

$$CONFIG = TLEN^2/AREA \quad (2)$$

A square lot on a straight shoreline has a configuration coefficient of 1.0. If CONFIG is greater than 1.0, the length of shoreline is large relative to the area of the lot. This parameter was used to evaluate associations between the shape of the cottage lot and the ADI.

2.4 RESULTS

Of the 1,036 cottage lots that had their lot size calculated, 85% were less than 0.55 ha. The lots selected for more detailed study ranged in size from 0.08 to 4.2 ha. The distribution of lot size was highly skewed with a mean of 0.38 ha, a median of 0.35 ha, and a mode of 0.25 ha (Fig. 2.3). The configuration of the lot was positively correlated with its area ($r = 0.624$, $P < 0.01$), because larger lots tended to have more shoreline per unit than did smaller lots. The cottage road that provides access to developed lots was located 76.2 m $\pm$ 30.6 m from the shoreline. On lots less than 0.1 ha in size, the road was usually closer to the shoreline; on lots of more than 1.0 ha, the cottage road seldom existed, being replaced by private lanes from a township road. There was no relationship between distance of the road from the lakeshore and lot size on lots between 0.1 to 1.0 ha in area.

The area of disturbed habitat in the three vegetation layers varied significantly ($P < 0.01$) with lot size, and the area cleared in the shrub layer was significantly larger ($P < 0.05$) than that cleared in the ground or tree layer (Table 2.2). The mean area disturbed on the lot was 1,333 m^2 broken down as ground (1,035 m^2), shrub (1,418 m^2) and tree (1,276 m^2) strata.

No significant differences were observed in the number of buildings on the lot or the distance of the major building from the water when these variables were compared in the different lot size classes. The mean number of buildings on a lot was 2.2 ($\pm$0.9), and its mean distance from water was 20.0 m ($\pm$12.3). There was a positive correlation between the total area of all buildings on a lot and its areas.

The ADI exhibited a significantly negative correlation with the area of the lot ($r = 0.875$, $P < 0.01$). Both linear and nonlinear techniques were used to fit the data (Dixon 1975).

Figure 2.2 A schematic representation of disturbance in the three layers of vegetation: tree, shrub and ground.

Table 2.1 Variable names and definitions.

Name	Description
AREA	Total area of the lot (ha)
TLEN	Total length of shoreline on the lot (m)
BUILD	The number of buildings on the lot
ABUILD	The total area of buildings on the lot
WATER	The distance of major building to water
Ag	Amount of area disturbed in ground layer
As	Amount of area disturbed in shrub layer
At	Amount of area disturbed in tree layer

The best-fitting equation for the ADI was obtained in a nonlinear regression of the form:

$$ADI = 1/(K_1(P_1 x\ AREA)) + K_2(P_2 x\ AREA)) + K_3) \quad (3)$$

Where $K_1 = 4.685$
$K_2 = 2.0$
$K_3 = 6.406$
$P_1 = 0.4163$
$P_2 = 1.256$
AREA = area of the lot (ha)

The predicted values from this equation and the observed means for lot size classes are illustrated in Figure 2.4.

A crude approximation of the ADI could be calculated from the number of cottages in the area:

$$ADI = CxLxD/AREA = 1 \times 3 \times 0.133/AREA \quad (4)$$

Where AREA = the size of area on which the disturbance is estimated (lot, plot, or land tract), C = number of cottages (1), L = number of layers of vegetation (3), D = average area disturbed per layer (0.133).

Table 2.2 Mean area disturbed and standard error for each of the lot size classes.

Area of lot (ha)	Ag	At	As	ADI
< 1.2	995 ± 81.6	995 ± 81.6	995 ± 81.6	2.406 ± 0.196
0.2-0.3	1555 ± 174.2	1624 ± 166.2	1584 ± 182.2	2.290 ± 0.208
0.3-0.4	1347 ± 199.5	1362 ± 196.1	1329 ± 204.9	1.358 ± 0.215
0.4-0.5	1309 ± 267.4	1356 ± 259.4	1359 ± 272.4	0.988 ± 0.195
0.5-0.6	1229 ± 89.9	1611 ± 273.6	1505 ± 282.2	0.853 ± 0.115
0.6-0.7	1473 ± 272.8	1562 ± 265.5	1388 ± 268.5	0.733 ± 0.131
0.7-0.8	1112 ± 235.9	1314 ± 284.7	987 ± 193.3	0.483 ± 0.091
0.8-0.9	1594 ± 452.5	1646 ± 447.0	1653 ± 447.3	0.463 ± 0.096
0.9-1.0	1209 ± 220.4	1269 ± 207.2	1081 ± 232.0	0.393 ± 0.07
> 1.0	1233 ± 262.5	1444 ± 330.2	883 ± 198.2	0.244 ± 0.051
Mean area	1305	1418	1276	

Ag = area disturbed in ground layer
At = area disturbed in tree layer
As = area disturbed in shrub layer
ADI = Area Development Index

2.5 DISCUSSION

The frequency distribution of lot sizes (Fig. 2.3) shows a large concentration in the 0.2 to 0.4 ha size categories. In the study area, 90% of the cottages were built on lots less than 0.33 ha. These results were very similar to those of previous surveys (Ontario 1968) but much smaller than the lots found in areas such as the French River Inlet of Lake Nipissing that are not heavily used (Moroz 1976). The small lots, particularly those which are less than 0.2 ha in size, can be expected to have a large ADI value, since the mean values of Ag, As and At were large (1,305 m^2, 1,418 m^2 and 1,276 m^2 respectively) compared to the size of the lot. The mean disturbed area around a cottage appeared to be relatively independent of lot size. This implies, that as lot size increases, there will be an expected increase in the amount of undisturbed area on the lot. These undisturbed areas were frequently located on the perimeter of the lot or on the border between two lots. This is

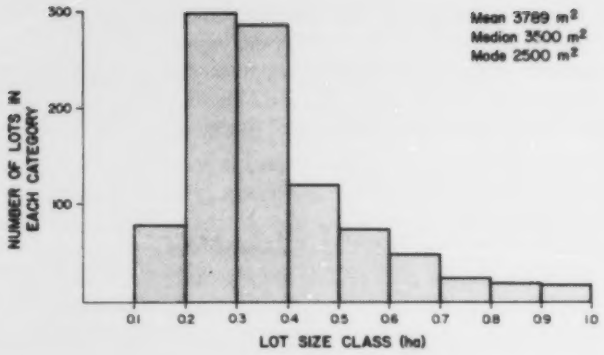

Figure 2.3 Frequency distribution of lot sizes in the study area.

particularly well pronounced on the long, narrow lots which parallel the shoreline.

Cottage roads were usually surveyed at the back of the lot. In ribbon developments, no lots were located on the inland side of the road. Therefore, habitat disturbance stopped at the road, excluding power and telephone lines.

Habitat disturbance varied considerably within the 0.3 and 0.4 ha size classes. This variability reflected the wide range of values and attitudes of cottagers. Moroz (1976) defines cottagers along a continuum ranging from the social cottager who attempts to maximize interaction so that the cottage takes on the attributes of a suburban home, to the wildland cottager to whom the natural environment is of primary impo tance. The importance of the ADI as a predictive tool should not be reduced by this variability although it would be beneficial to modify the predicted values upwards or downwards to account for particular social conditions or planned communities.

In most cases, the major factor affecting wildlife, runoff, or water quality is not the presence of the cottage itself but the cottager's activities and the destruction of habitat associated with cottage construction. The defined relationship between lot size and the ADI makes it possible to predict the proportion of area disturbed by development when a development proposal

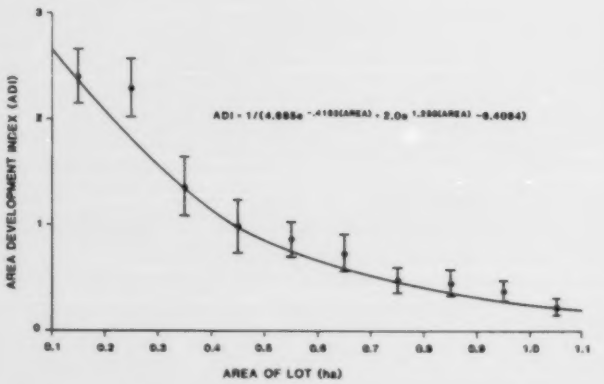

Figure 2.4 Non linear relationship between the Area Development Index (ADI) and the area of the cottage lot (AREA) showing the prediction line, the observed means and a 90% confidence interval. The prediction equation was derived, using lot sizees up to and including 3.9 ha.

is being considered. The ADI has also been used effectively as a dependent variable in the study of the response of small mammals to shoreline cottage development (Racey and Euler 1981). This characteristic makes the ADI compatible with some modelling applications as well (Racey et al. 1981).

Environmental quality could be related to aesthetics as well. Jackson et al. (1978) reported that people prefer landscapes with little evidence of other humans unless the setting is unique or rustic. The ability to quantify habitat disturbance permits quantitative comparisons of the visual environment (Buhyoff et al. 1977) or the assessment of the aesthetic value of the environment according to personal preferences (Jackson et al. 1978). Although accessibility by road contributes to the development of an area, individual cottage site location is based on the quality of the landscape (Standing 1971). In this province, where 94% of the cottages are used for personal use only (Ontario 1968), scenic amenities may be a determinant of cottage location (Moroz 1976). Some people are prepared to pay for frontage, depth of land, and spaciousness of environment (Abelson 1979). It is important, therefore, to consider aesthetic qualities of the environment when assessing development proposals. This becomes possible when the degree of habitat disturbance can be quantified and predicted.

2.6 CONCLUSIONS

An important aspect of modern environmental assessment is the ability to quantify the results. Quantification allows valid comparisons to be made between a development proposal and any alternative. The ADI predicts the amount of disturbance in the shoreline environment using cottage lot characteristics.

The ADI can be used as an environmental impact assessment tool by predicting changes in habitat from lakeshore cottage development. When used in conjunction with studies on wildlife (Racey and Euler 1981), the ADI also becomes a valuable modelling tool.

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3. HABITAT ASSOCIATIONS OF BREEDING BIRDS IN COTTAGED AND UNCOTTAGED AREAS OF CENTRAL ONTARIO

K. CLARK, D. EULER and E. ARMSTRONG

3.1 SUMMARY

Habitat associations of breeding birds in central Ontario were determined by measuring habitat characteristics at singing posts and nest sites and by using these variables in Principal Component and stepwise Discriminant Function Analyses. These results were then used as baseline data to predict avian responses to habitat disturbance caused by cottage development. Three habitat variables were important in accounting for large proportions of the total variance in all analyses. These were canopy volume, tree density, and amount of understory. The consistent importance of these variables in our analyses as well as in other published studies suggests that these variables may be significant in avian habitat selection. Coniferous composition was important in the Discriminant Function Analysis (DFA), and may be important as another measure of horizontal structuring of habitat.

By interpreting the positions of each species along the discriminant function and principal component axes, habitat associations could be described and predictions made regarding the response of a species to habitat disturbance from cottage development. Species associated with areas of low tree volume, low tree density, and little understory were the Song Sparrow *(Melospiza melodia)*, American Robin *(Turdus migratorius)*, and White-throated Sparrow *(Zonotrichia albicollis)*. These species were typical of those from highly disturbed habitats. The Black-throated Blue Warbler *(Dendroica caerulescens)*, Yellow-rumped Warbler *(Dendroica coronata)*, and Red-eyed Vireo *(Vireo olivaceus)* were associated with intermediate values of canopy volume, tree density and understory. These species should tolerate some habitat disturbance. The Swainson's Thrush *(Hylocichla ustulata)*, Black-throated Green Warbler *(Dendroica virens)*, and Ovenbird *(Seiurus aurocapillus)* were associated with high canopy volume and intermediate tree density indicative of undisturbed forests. These species would not be expected to tolerate even low levels of habitat disturbance.

3.2 INTRODUCTION

Limited information is available about the habitat relationships of forest-breeding birds in central Ontario where, in the last 25 years, increasing cottage development has led to widespread habitat alterations. Several studies have examined avian responses to habitat changes caused by logging (Kilgore 1971; Webb et al. 1977). However, these areas were allowed to revert to forest succession so the alterations were temporary. Cottage development results in long-term habitat alterations where complete removal of the natural vegetation does not often ocur and undisturbed forest patches are left between lakes. Whitcomb (1977) predicted that regional extinction of avian species would be common with the removal and fragmentation of forests. The species most vulnerable to extinction are neotropical migrants (Whitcomb 1977), the most common breeding species in central Ontario forests.

Based on the conclusion that the configuration of the habitat is a major factor influencing habitat selection in birds (MacArthur and MacArthur 1961; MacArthur et al. 1962; Hilden 1965; Anderson and Shugart 1974), various multivariate analyses can be used to quantify habitat relationships among species (James 1971; Holmes et al. 1979). These analyses indicate which habitat characteristics vary with the occurrence of each species. Although detailed descriptions of each species' habitat is not obtained, the results agree with the natural histories of the species (Conner and Adkisson 1977).

This approach allows the derivation of quantitative relationships between avian species and their habitats. These relationships can then be used as baseline data for managing forests and assessing the effects of vegetational changes on breeding bird populations (Anderson and Shugart 1974). The purpose of this study was to determine habitat associations of breedings birds in natural and cottaged habitats in central Ontario to provide baseline data for management of affected land areas.

3.3 STUDY AREA

The study was conducted in the Muskoka and Haliburton districts of central Ontario (Fig. 3.1). The area is comprised primarily of rolling, forested terrain with many lakes and rivers which have been subjected to varying intensities of cottage development. Some lakes are inaccessible by road, and the vegetation has not been extensively altered. Other lakes are circled by a road, a transmission line right-of-way, and a continuous ribbon of cottages so that much of the natural vegetation has been removed.

The study area is located in the ecotone between the Boreal and the eastern deciduous forests. It is characterized by a mixture of White Pine *(Pinus strobus)*, Balsam Fir *(Abies balsamea)*, and Eastern Hemlock *(Tsuga canadensis)*, particularly along north-facing shorelines. Sugar Maple *(Acer saccharum)* and Red Maple *(A. Rubrum)* are common along south-facing shorelines, White Birch *(Betula papyrifera)* and

Figure 3.1 The study area.

White Cedar *(Thuja occidentalis)* within 10 m of shore, and Beech *(Fagus grandifolia)* and Yellow Birch *(Betula lutea)* more than 20 m from shore.

3.4 METHODS

Seventy-three lakeshore study plots, 100 x 100 m each, were selected to represent the range of cottage development and habitat types in the area. In 1977 and 1978 singing males were censused by the spot map method (Kendeigh 1944) for four hours between 0500 and 1100. The census was repeated three times between May 26 and July 20. Locations of any nests within these plots were also recorded.

Table 3.1 lists 22 vegetation variables which were measured, using a modification of the rangefinder method (Anderson and Shugart 1970) in 0.04-ha circular plots centred on a singing post of a territorial, male bird or on a nest. Since it was not possible to describe the singing posts of all species (Table 3.2), birds were chosen to represent the range of available habitat. For 12 species, adequate samples were obtained to allow measurements at nest sites (Table 3.2).

Principal Component Analysis (PCA) (Anderson 1958; Morrison 1967) was used to obtain ordinations of the species along vegetational gradients. The theory and ecological application of the PCA has been discussed elsewhere (James 1971; Gauch and Whittaker 1972). Singing posts and nest sites were analysed separately. All 22 vegetation variables were used in each analysis. The BMD-P4M (Dixon 1975) computer program was used. An ordination was obtained by plotting the mean factor score for each species on the first three principal component axes.

A stepwise DFA was used to select the vegetation variables which were important in describing species habitat associations. Only eight species had an adequate sample size to be included in the DFA. The BMD-P7M computer program was used.

Table 3.1 Vegetation variables used in the analysis of nest sites and singing posts.

Mnemonics	Description
CANVOL	Canopy volume (TVOL x CANHT) /10*
TVOL	percent tree volume
TCOV	tree coverage*
CANHT	Canopy height
TIND	number of tree individuals
TREE 1	number of trees 8 - 16 cm DBH*
TREE 2	number of trees 16.1 - 24 cm DBH*
TREE 3	number of trees 24.1 - 32 cm DBH*
TREE 4	number of trees 32.1 - 40 cm DBH*
TREE 5	number of trees 40.1 + cm DBH*
TSP	number of tree species*
PCCT	percent conifer composition of the trees*
TSNAG	number of tree snags
SVOL	percent shrub volume
SCOV	shrub coverage*
SHIND	number shrub individuals
SHSP	number of shrub species
PCCSH	percent conifer composition of the shrubs
SHSNAG	number of shrub snags
GVOL	percent ground volume
GCOV	ground coverage
FHD	foliage height diversity**

*Variables used in the discriminant function analysis
**Based on MacArthur and MacArthur (1961)

Table 3.2 Species and sample sizes used in the analysis of nest sites and singing posts and the corresponding symbols used in figures 3.1 to 3.4*.

Symbol	Species	Sample Size	
		Singing Posts	Nests
PHOE	Eastern Phoebe *(Sayornis Phoebe)*	27	10
LFLC	Least Flycatcher *(Empidonax minimus)*	30	6
EWPE	Eastern Wood Pewee *(Contopus virens)*	18	-
ROBN	American Robin *(Turdus migratorius)*	30	10
SWTH	Swainson's Thrush *(Hylocichla ustulata)*	21	-
VEER	Veery *(Hylocichla fuscescens)*	30	12
REVI	Red-eyed Vireo *(Vireo olivaceus)*	30	10
BWWA	Black and White Warbler *(Mniotilta varia)*	30	-
YRWA	Yellow-rumped Warbler *(Dendroica coronata)*	30	5
BTGR	Black-throated Green Warbler *(Dendroica virens)*	30	-
BTBW	Black-throated Blue Warbler *(Dendroica caerulescens)*	30	6
BBWA	Blackburnian Warbler *(Dendroica fusca)*	30	-
OVBD	Ovenbird *(Seiurus aurocapillus)*	30	7
ARMS	American Redstart *(Setophaga ruticilla)*	-	13
SOSP	Song Sparrow *(Melospiza melodia)*	30	-
WTSP	White-throated sparrow *(Zonotrichia albicollis)*	30	0
RBGB	Rose-breasted Grosbeak *(Pheucticus ludovicianus)*	30	9
YBSS	Yellow Bellied Sapsucker *(Sphyrapicus varius)*	-	12
BWHA	Broad-winged Hawk *(Buteo platypterus)*	-	9

*Species with a sample size less than 9 were not used in the DFA.

3.5 RESULTS

3.5.1 PRINCIPAL COMPONENT ANALYSIS

The first principal component for singing posts accounted for 21.1% of the total variance, and was highly correlated with canopy volume, tree volume, tree cover, and canopy height (Table 3.3). Birds found in mature forests with a dense canopy would be expected to score highly on this component. Species found in the open habitats of highly developed areas in which most of the large trees had been removed would be expected to score low values on this component. The second principal component accounted for 13.8% of the total variance, and was highly correlated with number of tree individuals, number of trees (8-16 cm), and number of trees (16-24 cm). Species found in early successional forests where there were many small trees, as along the edge of cottage clearings, would be expected to have high scores on this component. Intermediate scores on this component should coincide with undisturbed mature forests, whereas low scores should coincide with open areas and disturbed forest habitats in which most of the trees had been removed. The third component accounted for 10.5% of the total variance, and was highly correlated with ground volume, ground cover, number of shrub species, and number of shrubs. Species associated with high values of this component should be found where there is a dense understory as along forest edges, transmission lines and road rights-of-way. Species with low scores were predicted to occur in mature forest, especially coniferous, or where the understory had been cleared. Overall, the first three principal components for singing posts accounted for 45.5% of the total variance.

Table 3.3 Summary of the results of the principal component analysis of 22 vegetation variables for 16 breeding bird species' singing posts.

	Component Correlations to Original Variables*		
Vegetation Variable	1 (21.1)**	2 (34.9)	3 (45.4)
Canopy Volume	0.941	0.0	0.0
Percent Tree Volume	0.868	0.0	0.0
Tree Coverage	0.841	0.0	0.0
Canopy Height	0.709	0.0	0.0
No. Tree Individuals	0.0	0.859	0.0
No. Trees 8-16 cm DBH	0.0	0.811	0.0
No. Trees 16-24 cm DBH	0.0	0.797	0.0
Tree Species	0.0	0.503	0.0
Ground Volume	0.0	0.0	0.848
Ground Cover	0.0	0.0	0.792
Shrub Species	0.0	0.0	0.709
Shrub Individuals	0.0	0.0	0.627
Shrub Volume	0.0	0.0	0.0
Shrub Cover	0.0	0.0	0.0
Conifer Composition Shrubs (%)	0.0	0.0	0.0
Conifer Composition Trees (%)	0.0	0.0	0.0
No. Trees 24-32 cm DBH	0.0	0.374	0.0
No. Trees 32-40 cm DBH	0.285	0.0	0.0
Shrub Snags	0.0	0.0	0.0
Tree Snags	0.0	0.276	0.0
Foliage Height Diversity	0.380	0.0	-0.253
No. Trees 40.1+ cm DBH	0.455	-0.256	0.0

*The rows have been rearranged so that for each successive factor, loadings greater than 0.50 appear first. Loadings less than 0.2500 have been replaced by zero.

**Cumulative Percentage of variance explained.

The results of the PCA of the variables measured at nest sites were very similar to those at singing posts. The first three principal components included the same variables with slight differences in the order of importance of the variables (Table 3.4). Overall, the first three components for nest sites accounted for 51.9% of the total variance.

Table 3.4 Summary of the results of the principal component analysis of 22 vegetational variables for 12 bird species' nest sites.

	Component Correlations to Original Variables*		
Vegetation Variable	1 (26.3)**	2 (40.8)	3 (51.9)
Canopy Volume	0.913	0.0	0.0
Tree Volume	0.862	0.291	0.0
Tree Coverage	0.832	0.0	0.0
Canopy Height	0.795	0.0	0.0
No. Trees 32.1 - 40 cm DBH	0.575	0.0	0.0
No. Trees 40.1+ cm DBH	0.549	0.0	0.0
Foliage Height Diversity	-0.509	-0.333	0.0
No. Tree Individuals	0.0	0.922	0.0
No. Trees 8 - 16 cm DBH	0.0	0.866	0.0
No. Trees 16.1 - 24 cm DBH	0.0	0.829	0.0
Ground Volume	0.0	0.0	0.880
No. Shrub Individuals	-0.281	-0.288	0.795
Shrub Species	0.0	0.0	0.746
Ground Cover	0.319	0.0	0.729
Shrub Volume	0.0	0.0	0.0
Shrub Snags	0.0	0.0	0.0
Shrub Cover	0.0	0.0	0.394
Conifer Composition Trees (%)	0.0	0.0	0.0
Conifer Composition Shrubs (%)	0.0	0.0	0.0
Tree Species	0.0	0.425	0.0
Tree Snags	0.0	0.501	0.0
No. Trees 24.1 - 32 cm DBH	0.422	0.359	0.0

*The rows have been rearranged so that for each successive factor, loadings greater than 0.5000 appear first. Loadings less than 0.2500 have been replaced by zero.

**Cumulative Percentage of Variance Explained.

Using the mean of the factor scores of all individuals of each species, a three-dimensional ordination of the species in habitat space was produced. The axes were described by the eigenvectors associated with the first three principal components. This allowed a visual presentation of habitat relationships in which the distance from one species to another was proportional to the difference between them (Isebrands and Crow 1977).

Figures 3.2 and 3.3 show the habitat ordination of singing posts and nest sites respectively. The axes in both figures are associated with similar habitat characteristics. The first axis corresponds to increasing canopy volume, and separates the open country birds from the forest birds. For singing posts, the Ovenbird, Swainson's Thrush, and Black-throated Green Warbler scored highly on this component while the Song Sparrow, American Robin, and White-throated Sparrow had very low scores.

The second axis is associated with increasing tree density. For singing posts, the Black and White Warbler had the highest score on this axis while the Robin had the lowest. For nest sites, the Least Flycatcher, Black-throated Blue Warbler, and Ovenbird had very high scores while the Robin and Eastern Phoebe had low scores.

The third axis is associated with increasing amount of

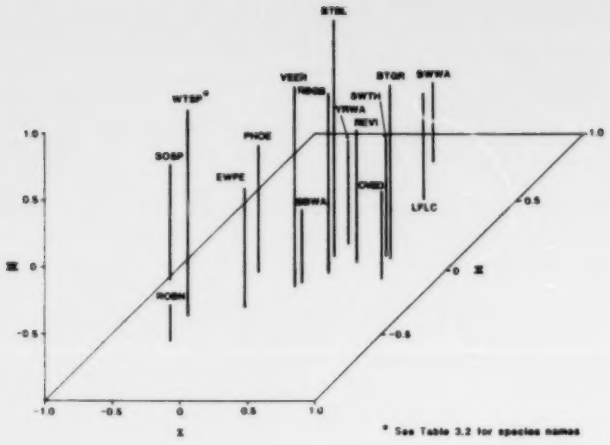

Figure 3.2 Representation of the first three axes of the habitat ordination of bird species singing posts. A description of each axis is given in the text.

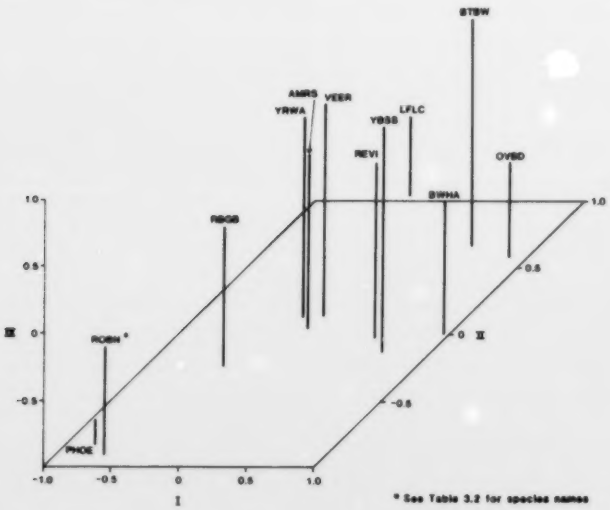

Figure 3.3 Representation of the first three axes of the habitat ordination of bird species nest sites. A description of each axis is given in the text.

understory. For singing posts, the Black-throated Blue Warbler and Robin scored at the high and low extremes of this component respectively. For nest sites, the Black-throated Blue Warbler, and Yellow-Bellied Sapsucker *(Sphyrapicus varius)* had very high scores while the Phoebe and Yellow-rumped Warbler had very low scores.

3.5.2 DISCRIMINANT FUNCTION ANALYSIS

The DFA requires that the number of variables not exceed the sample size of the smallest group. To meet this requirement, the number of vegetation variables was reduced to nine, and any species with a sample size less than nine was eliminated (Table 3.2). The vegetation variables which were included in the DFA had to be indicative of the main habitat types and could not show high correlations with any of the former variables. Because of the high correlations among them, the three smallest size classes and the two larger classes for trees were summed to give a single measure of the number of small and large trees respectively.

Four variables were used to differentiate each species' singing post (Table 3.5). The absolute value of the coefficients indicated the relative contribution of each variable to the respective discriminant function axis. The number of small trees, and to a lesser extent, tree cover and percent conifer composition were major contributors to the first discriminant function axis. Tree cover and ground volume were the major contributors to the second and third axis respectively. An ordination of the species means along the first three discriminant function axes is shown in Figure 3.4.

Table 3.5 Standardized discriminant function coefficients for the first 3 discriminant functions for 15 species' singing posts.*

	Discriminant Function		
Vegetation Variable	I	II	III
No. of trees 8 - 32 cm DBH	-0.0436	0.0168	0.0361
% Tree coverage	-0.0410	0.0812	-0.0226
Ground Volume	-0.0159	-0.0004	-0.0939
% Conifer composition of trees	-0.0383	-0.0152	-0.0016

*Variables used in the analysis are indicated in Table 1.

Shrub cover was the only variable entered in the stepwise DFA of nest sites. A line graph was drawn to illustrate the ordination of species along this axis (Fig. 3.5).

3.6 DISCUSSION

The vegetation variables indicated by the PCA to be of great importance in describing the variation in this data set agree closely with similar studies by James (1971), Whitmore (1977), and Smith (1977), even though different avian communities and habitats were studied in each case (Table 3.6). The first two principal components of our study and Smith's (1977) both describe habitat variables associated with canopy and tree density. James' (1971) and Whitmore's (1977) results describe similar vegetation characteristics as our study and Smith's (1977), although there are some differences in the order of importance of variables to each component. This can be attributed to differences in the range of vegetation

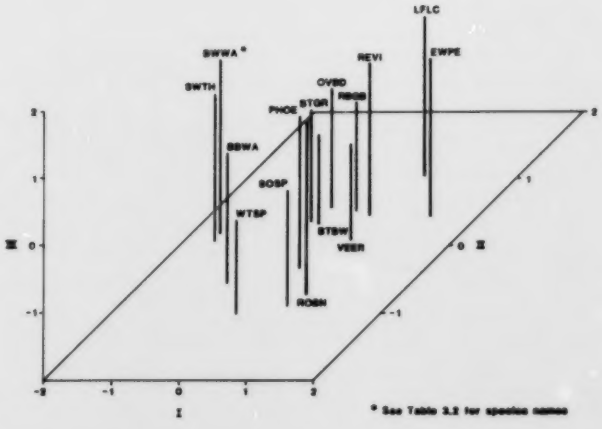

Figure 3.4 Ordination of bird species singing posts along first three discriminant function axes. A description of each axis is given in the text.

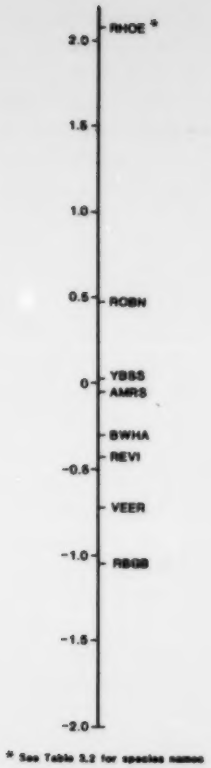

Figure 3.5 Ordination of bird species nest sites. This axis describes a gradient of increasing shrub cover.

variables sampled in each study. James (1971) sampled mainly deciduous woods in Arkansas in which there were a large number of tree species with a range of heights. Whitemore (1977) sampled open field and forest in Utah of relatively uniform height and dominated by only two tree species. Smith (1977) sampled a forest moisture gradient in Arkansas along which there was a variety of deciduous tree species. Our study included shoreline with coniferous, mixed, and deciduous forest as well as forest altered by cottage development.

The lower proportion of total variance explained in our study and that of Smith's (1977) in contrast to that explained by James (1971) and Whitmore (1977) can be attributed in part to their use of mean values for each vegetation variable for each species, fewer vegetation variables, and their sampling of a more restricted range of habitat types.

In Utah, Whitemore (1975) found the four most important variables selected by the DFA were percent canopy cover, percent shrub density, number of small trees, and percent ground cover. With the exception of percent conifer composition which was not considered in Whitmore's study, these results are comparable to those of our study. Canopy cover was also found to be the most important variable in a similar study done in Arkansas by James (1971), although her results differed for other variables.

The close similarity of the PCA for song posts and nest sites further indicates the importance of canopy volume, tree density, and amount of understory in the distribution of individuals throughout the habitat. This similarity also suggests that these vegetational characteristics may be of general significance with regard to satisfying different habitat requirements of different avian species.

Avian habitat selection is considered to be primarily based on proximate factors involving the general vegetative structure, substrate and terrain (Holmes et al. 1979, Rotenberry and Wiens 1980). The consistent importance of canopy volume, tree density and amount of understory in our analyses as well as those of James (1971), Whitmore (1975), and Smith (1977) suggests that these vegetational characteristics may be important in terms of specific search images used by birds for habitat selection. There are several possible reasons why these vegetation variables may be important in predicting avian habitat selection.

The canopy layer is important because it adds vertical structure to the habitat providing another dimension for potential food sources, shelter from predators, inclement weather, and nest sites (Franzreb 1976; Holmes et al. 1979). Willson (1974) found that the greatest variation in species compostion occurred when the canopy layer was added to a habitat. Canopy volume has been shown (Morse 1971) to predict the habitat selection of spruce-dwelling Wood Warblers *(Parulidae)*. Sturman (1968) found that canopy volume was associated with the relative abundances of two Chickadee *(Parus* spp.*)* species.

Tree density or the number of small trees may be an important measure of relative tree size. Tree size may be important in habitat selection because of preferences of some species for certain trunk diameters and heights for singing posts, foraging, and nest sites (Morse 1967, 1968; Dickson and Noble 1978).

Table 3.6 Comparison of the results of the principal component analysis with published studies.

	This Study	James 1971*	Whitmore 1977*	Smith 1977
Variables Highly Correlated with the:				
First Principal Component	CANVOL TVOL TCOV CANHT	TSP TCOV TREE 2 TREE 1 CANHT	GCOV -TREE 3	TCOV**
Second Principal Component	TIND TREE 1 TREE 2	SHIND/4	SHIND	TREE 2†
Total Variance Explained by the first 2 Principal Components %	35	77.3	73.5	32.2
Number of Bird Species in the Analysis	15	46	24	8
Number of Vegetation Variables in the Analysis	22	10	10	25
Location of Sampling	Central Ontario forests, cottaged lots	Arkansas forests, wetlands	S.W. Utah cottonwood forest, wetlands, farmland	N.W. Arkansas forest moisture gradient

*PCA was performed using the mean of each habitat variable for each species.
**This principal component also includes number of post oak 22.9 cm DBH., number of black hickory (−), number of post oak 22.9 cm DBH.
†This principal component also includes number of shagbark hickory, number of beech 22.9 cm DBH.

The effect of ground volume on species distribution may be explained by Roth's (1976) suggestion that increasing ground and shrub volume results in greater spatial heterogeneity. Coniferous composition may be important as another measure of horizontal structuring of the habitat, since conifers provide both an inner and outer layer for which particular species are specialized (MacArthur 1957). Studies relating species diversity to foliage height diversity (MacArthur 1957) have been inconsistent which suggests that other factors must influence species distribution (Balda 1969; Kilgore 1971; Stamp 1978; Holmes et al. 1979).

Shrub cover may be important in nest site selection because it could determine different types of concealment from predators and the amount of protection from inclement weather. Shrub cover has been found by Bertin (1977) to be the single most important factor that distinguishes Wood Thrush from Veery territory. Kilgore (1971) found that removal of the ground and lower shrub layers can result in changes in species composition of these layers but does not affect the canopy layer. Since all species examined except the Broad-winged Hawk were found to nest in the ground or shrub layers, other habitat characteristics could have been important if more canopy nesters had been included.

By interpreting the positions of each species along the principal component and discriminant function axes, habitat preferences can be described and predictions made regarding a species' response to cottage development.

The White-throated Sparrow, Song Sparrow, and American Robin were associated with habitats typified by low canopy volume and tree density, shrubby areas and lawns in highly developed habitats. The White-throated Sparrow, usually considered a Boreal forest bird (Kendeigh 1948; Martin 1960) was associated with high coniferous composition and dense understory. Its preference for an open canopy with a well-developed understory makes it well suited to inhabit cottaged lots in coniferous woods where most of the tree layer has been removed. The Song Sparrow was associated with mixed conifer composition and a reduced understory found in cottaged areas where much of the vegetation had been removed. The Robin, often an urban species (Howell 1942; Young 1955; Howard 1974), was associated with very low ground volume and mixed coniferous composition for its singing posts and similar habitat with low shrub cover for its nest sites. Its ability to nest on drainpipes and ledges and its preference for open areas for foraging allows the Robin to be successful in highly developed areas where most of the natural vegetation has been removed.

The Phoebe and Eastern Wood Pewee were associated with slightly higher canopy volume and tree density, features indicative of the periphery of a clearing. Both the Phoebe and Pewee require and open area for flycatching (Hespenheide 1971; Kilgore 1971) and some canopy for perching. The Phoebe's preference for low shrub cover and its nest location on buildings makes it able to inhabit cottaged lots with small clearings which allow for adjacent nesting and foraging habitat. Hespenheide (1971) classified the Pewee as an edge species, since the main criterion for its presence is a discontinuity in the canopy layer in close proximity to open areas for foraging and trees for perches and nest sites. The Pewee could be found on the forest edges of cottage clearing regardless of lot size.

Although the Blackburnian Warbler and Veery occupy a different feeding guild, they were both associated with intermediate canopy volume and slightly less than mean tree density. The Blackburnian Warbler was found in coniferous woods with little understory. It is usually associated with a high canopy for foraging (Griscom and Sprunt 1957; Morse 1976) suggesting that it is found on cottage lots in mature woods where the canopy layer has not been disturbed or in undisturbed forests. The Blackburnian Warbler is negatively affected by even low levels of disturbance (Webb et al. 1977), probably because they forage along the outer twigs and branches (Holmes et al. 1979).

The singing posts of the Veery were in deciduous woods with a well-developed understory. Nest sites were associated with intermediate canopy volume, tree density, and very high shrub coverage as found by Bertin (1977) as well. The Veery would be expected to benefit from a pattern of tree removal in mature forests where the understory was not disturbed, resulting in greater shrub cover and development of the understory.

The Black-throated Blue Warbler, Yellow-rumped Warbler, and Red-eyed Vireo were associated with intermediate levels of canopy volume and tree density indicative of selective tree removal in mature woods or of immature woods which in our study area were usually associated with forest succession on cleared lots. The Black-throated Blue Warbler was found in mixed or deciduous woods with moderate canopy volume and tree density. The Black-throated Blue Warbler requires a greater amount of understory. Webb et al. (1977) found that removal of the tree layer did not change the population density of the Black-throated Blue Warbler which suggests that disturbance of the canopy layer should not affect its nesting habitat. Although the Black-throated Blue Warbler forages among the outer twigs and branches (Holmes et al. 1979), it is capable of using a variety of canopy heights and volumes.

The Yellow-rumped Warbler was associated with mixed woods with some understory. This species has been shown to exhibit a high degree of plasticity in habitat preferences for foraging and nesting (Ficken and Ficken 1967; Morse 1971; Franzreb 1976; Dickson and Noble 1978), and is dependent to some extent on competitive displacement (Morse 1976).

The Red-eyed Vireo was associated with deciduous woods with some understory for singing posts and nest sites. The Red-eyed Vireo has been found to tolerate varying degrees of tree removal (Webb et al. 1977), since it has been reported in habitats ranging from dense shrubs to mature forest (Kendeigh 1948; Rice 1978). Conner and Adkisson (1975) and Adams and Barrett (1975), however, found the Red-eyed Vireo intolerant of tree removal, suggesting that in some areas other factors such as competitive interactions may be important in the habitat selection of this species.

The singing posts of the Rose-breasted Grosbeak were associated with deciduous woods with a dense understory. Nest sites had a low canopy volume and very high shrub cover typical of immature trees where it has been noted to nest in other parts of its range (Kendeigh 1946, 1948; Kricher 1973). The preference for high tree density and extensive shrub cover leads the Rose-breasted Grosbeak to inhabit areas where large trees have been removed and the understory has been allowed to develop (Webb et al. 1977; Possardt and Dodge 1978).

The Swainson's Thrust, Black-throated Green Warbler, and Ovenbird were associated with high canopy volume and

intermediate tree density indicative of undisturbed forests. The Swainson's Thrush was associated with high conifer composition and little understory. There is little information available about the nesting habitat of this species. Its association with mature woods suggests an intolerance of any habitat alteration. Webb et al. (1977), however, found that it was not affected by intense logging. Since the Swainson's Thrush nests in the shrub layer, habitat alterations affecting this stratum may be more critical to its occurrence.

The Black-throated Green Warbler was associated with coniferous, mature woods with considerable understory. MacArthur (1958) and Morse (1971) noted a high degree of stereotypy in habitat utilization leading to narrow habitat use for this species. These specialized habitat requirements would explain its limitation to undisturbed coniferous woods (Morse 1976; Webb et al. 1977).

The Ovenbird was associated with mixed woods with little understory typical of undisturbed mature forests. Several studies have noted population declines with tree removal (MacClintock et al. 1977; Whitcomb et al. 1977; Conner and Adkisson 1975), although Adams and Barrett (1976) found a population increase. The Ovenbird would be expected to be found near cottaged lots in mature woods if human activity did not disturb this ground nesting species.

The Black and White Warbler and Least Flycatcher were associated with high tree density and high canopy volume typical of an area which had been cleared and allowed to proceed to an early successional forest stage.

Although the Black and White Warbler is considered to be a deciduous forest bird (Harrison 1975), it was associated with high conifer composition in our study area. Since it is a ground nester, it would not be expected to tolerate extensive human activity. Possardt and Dodge (1978) have shown that disturbance of the understory results in a population decline.

The singing posts and nest sites of the Least Flycatcher were associated with deciduous woods. The Least Flycatcher is a forest bird found near semi-openings in the canopy (Kendeigh 1948; Breckenridge 1956; Hespenheide 1971). Mature forests subject to selective tree removal to open the canopy should provide favourable habitat, whereas extensive tree removal or reduction of the understory should create unsuitable habitat for this species (Webb et al. 1977; Possardt and Dodge 1978).

The PCA and DFA proved reliable in determining avian habitat relationships and the effects of habitat alterations on avian distributions. The information obtained compared favourably with studies involving extensive, long-term data collection (Webb et al. 1977; Bertin 1977; Rice 1978). Our results suggest that reasonably accurate measures of species habitat relationships can be obtained by measuring only four habitat characteristics: canopy volume, tree density, shrub coverage, and percent conifer composition (which would only apply to areas with variation in conifer composition).

As Holmes et al. (1979, have recently shown, patterns of avian distribution are also influenced by forest plant species composition. In the management of habitat for a variety of purposes, plant species composition has to be considered in addition to the structural features considered in this study.

3.7 ACKNOWLEDGEMENTS

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4. THE IMPACT OF COTTAGE DEVELOPMENT ON COMMON LOON REPRODUCTIVE SUCCESS IN CENTRAL ONTARIO

M. HEIMBERGER, D. EULER and J. BARR

4.1 SUMMARY

The impact of cottage development on loon reproductive success was investigated by comparing lakes with no cottages to lakes with several different levels of development. As the number of cottages within 150 m of a nest increased, hatching success declined. There was significantly more human activity near nests when cottage density was high. Some loons nesting in developed areas may become habituated to human activity while others may not have this capability. In general, cottage development reduces loon reproductive success.

4.2 INTRODUCTION

In recent years, the increasing popularity of wilderness vacations has caused a sharp rise in recreational activity in some prime northern areas. In the Boundary Waters Canoe Area of Minnesota, motorboat and canoe traffic has increased 44 and 55 percent respectively from 1961-66 (Lucas 1967). This appears to be having a negative impact on the productivity of the Common Loon *(Gavia immer)* (Titus 1979). Lehtonen (1970) attributed the decline in the Arctic Loon *(G. arctica)* on Finnish lakes to increasing numbers of cottages. In a one year study of 19 Alberta lakes, Vermeer (1973) found a significant, inverse correlation between the numbers of breeding Common Loons and the amount of human disturbance. In this study we investigated the impact of cottage development on the reproductive success of this species in central Ontario.

4.3 STUDY AREA AND METHODS

The study area was located in the Muskoka and Haliburton Districts of central Ontario (Fig. 4.1). It lies within the Georgian Bay-Ottawa Valley physiographic region (Chapman 1975) where the bedrock of the Canadian Shield exerts a dominant influence on the landscape. The majority of the lakes within the area are oligotrophic. Vegetation characteristic to the area is that of the Great Lakes-St. Lawrence Forest (Rowe 1972). Along north-facing shorelines, a mixture of white pine *(pinus strobus)*, balsam fir *(Abies balsamea)*, and eastern hemlock *(Tsuga canadensis)* is common. Deciduous species like the sugar maple *(Acer saccharum)*, red maple *(Acer rubrum)*, and white birch *(Betula papyrifera)* are found along south-facing shorelines.

The lakes selected for study were 31–190 ha in area, and were similar except for intensity of cottage development. Each potential Common Loon territory had to meet the requirements set by Olson and Marshall (1952). Each included open water, free of emergent vegetation, sufficient

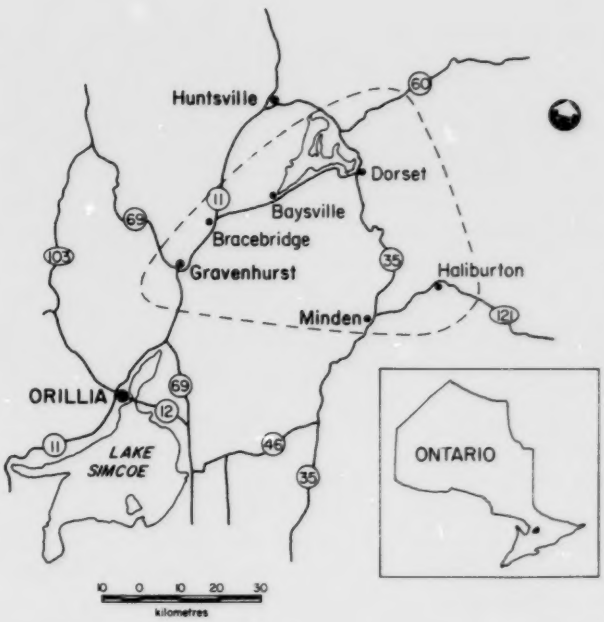


Figure 4.1 Map of the study area.

room for display activity, a loafing area and adequate food for a pair of adult loons with chicks. A bog or small island was considered essential for nesting. The level of development along the lakeshores ranged from totally undeveloped to a maximum of more than 10 cottages/500 m.

All islands, bogs, and mainland shore areas with bog fringes were surveyed once every two weeks between May–November 1977. Thirty-four lakes were surveyed. In 1978 and 1979, one lake was eliminated, and seven added for a total of 40 lakes. These represented approximately 50 potential Common Loon territories.

Nest locations and clutch sizes were recorded. The date on which incubation was initiated was determined by subtracting 28 days (the incubation period of this species) from the date of hatching. Where eggs failed to hatch, only the date on which the nest was found was recorded. The number of hatched eggs was calculated by counting the chicks and/or the shell membranes. When the chicks were first seen, their age was determined by their size and the colour of their plumage (Olson and Marshall 1952). This method is accurate to within three days.

The z-test of the difference between the parameters of two

Table 4.1 Summary of Common Loon reproductive success in 1977, 1978 and 1979.

	1977	1978	1979
No of potential loon territories	44	50	50
No. of potential territories occupied	29	38	35
% potential territories occupied	65.9	76	70
No. of territories with at least one nesting attempt	24	33	29
% territorial pairs with at least one nesting attempt	82.7	86.8	82.8
% potential territories with at least one nesting attempt	54.5	60	58
No. of terrorities with at least one egg hatching	17	23	20
No. of nesting attempts	28	43	39
No. of eggs laid	49	71	59
No. of eggs hatching	28	44	28
% nest success	60.7	53.4	51.2
% chick survival	67.8	75	85.7
No. of chicks fledged per nesting pair	0.8	1	0.8
No. of chicks fledged per successful pair	1.1	1.4	1.2
Mean No. of eggs in successful nests	1.9	1.9	1.6
Mean No. of eggs in unsuccessful nests	1.4	1.3	1.3

binomial distrubtions was used to compare the number of chicks fledged per nesting pair of loons in the three years. This test was also used to evaluate the difference between the success rate of first nesting and subsequent attempts (Remington and Shork 1970).

The number of cottages within 150 and 250 m of Common Loon nests was recorded. The straight line distance from a successful nest to the nearest cottage was compared to that between an unsuccessful nest and the nearest cottage. A chi-square test statistic was used to test the null hypothesis that development within 150 m of a possible nesting area had no effect on its selection.

In 1979, human activity around 16 nests was investigated. There were no cottages within 250 m of eight nests and so, these were classified as undeveloped. The remaining eight nests were considered developed as they were located within 150 m of a minimum of three cottages. Each nest was monitored on four different weekend days unless it was raining. Monitoring was done during one of four time periods (0700-0830; 1000-1130; 1300-1430; 1600-1730) during the incubation period.

The type and location of all human activity observed within 500 m of the nest was recorded on a grid map once every five minutes for each time period. Human activity observed within 500 m of the nest was closely examined because it was assumed that activity close to the nest would have a greater detrimental effect on loon reproduction than that further away. For each nest, the sum of the observations of a given activity occurring within 75 m of the nest over the four time periods was calculated and then multiplied by four. Similarly, activity which occurred 75–150 m from the nest was multiplied by three. For a given activity, the two weighted sums were added together, giving a weighted sum for that activity observed over four periods for a given nest. The average for an activity observed per undeveloped nest was derived by summing the weighted totals for each underdeveloped nest and dividing by eight. The average per developed nest was similarly calculated.

In 1979 habitat analyses were conducted on 38 loon nests. A circle of 2.0 radius was centred on the nest, and five 1.0-m^2 subplots were arranged within the circle (Fig. 4.2). The shoreline transect, centred on the nest, ran parallel to the shoreline, and the backshore transect bisected it at right angles. (Appendix I).

The habitat of potential nesting areas was also analysed. The number of potential nesting areas on each loon territory was recorded. Thirty-six areas of a total of 219 were randomly chosen from all islands and bogs on the study lakes. Habitat conditions around successful nests were compared to those around unseccessful nests. The actual nests were then compared to the 36 potential sites. The measured variables (Appendix I) were reduced to a list of those that most commonly assumed non-zero values, and were used in a Principal Component Analysis (PCA) (Appendix II). (BMD-P4M Dixon 1975). Its ecological applications have been discussed by James (1971) and Gauch and Whittaker (1972). Stepwise Discriminant Function Analysis (DFA) was used to select the vegetative and physical variables most important for the comparisons mentioned above. (BMD-P7M Dixon 1975).

Table 4.2 Distance from cottage(s) to Common Loon nests*.

Distance (m)	No. of Successful Nests	No. of Unsuccessful Nests
0-200	27	29
201-400	8	14
401-600	8	5
>600	9	1
Totals	52	49

* χ^2 = 8.36, P≤ 0.05, df = 3 (for combined 1977, 1978 and 1979 data)

A score that established the position of each group along the discriminant function axis was computed. The mean of each habitat variable was multiplied by the appropriate coefficient, and the values were totalled. The upper and lower limits of each group were obtained by adding and subtracting the standard deviation from the mean value of each habitat variable in every group.

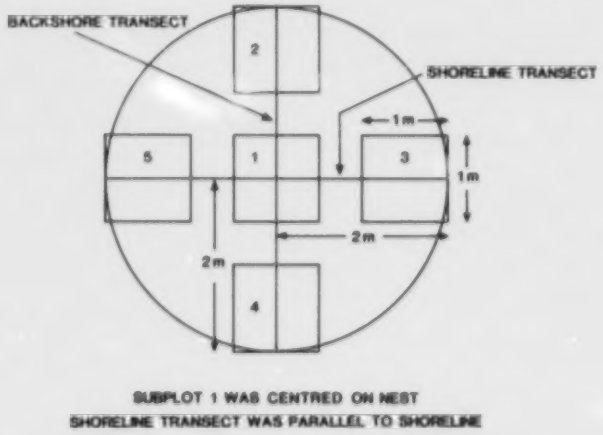


Figure 4.2 Habitat analysis plot for actual loon nests and possible nesting sites.

4.4 RESULTS

Although the number of chicks fledged per nesting pair and per successful pair (loons with at least one egg hatching) appeared to have been higher in 1978 than in either 1977 or 1979 (Table 4.1), the overall differences in the data of the three years were not significant (z-test; $P<0.05$). During 1979 fewer eggs hatched, but a greater percentage of chicks survived to the fledgling stage than in the other two years. These differences were not significant (z-test; $P<0.05$).

The mean number of eggs in successful nests was significantly higher (t-test; $P<0.01$ for 1977 and 1978; $P<0.05$ for 1979) than the number of eggs in unsuccessful nests (Table 4.1). When successful nests of 1977 were compared to those of 1978, the number of eggs was not significantly different. Similarly, the number of eggs in unsuccessful nests in the three years was not significantly different (t-test). However, the number of eggs in successful nests of 1979 was significantly lower ($P<0.01$) than in 1977 and 1978 (t-test).

Twenty-two nests out of a three year total of 110 represented renest attempts. Comparisons of first nesting to subsequent attempts indicated that success rates were not significantly different (z-test; $P<0.05$). Initial attempts had a success rate of 51.8 compared to 59.1 percent for those subsequent. The mean clutch size of first nesting attempts was 1.76 ± 0.43 compared to 1.55 ± 0.51 in subsequent tries. This difference was significant (t-test; $P<0.05$).

Incubation initiated after the third week of June was not as successful as that started earlier (Fig. 4.3). There was no distinct peak in the dates of the beginning of incubation in 1977. The peak in 1979 occurred one week later than in 1978. In 1979 peak hatching took place three weeks later than in the previous two years. The success rate of nests increased with distance from the nearest cottage (Table 4.2). As cottage density increased, the success rate declined (Table 4.3).

Table 4.3 Cottage density and Common Loon nesting success.

No. of Cottages Within 150 m of the Nest*	No. of Successful Nests	No. of Unsuccessful Nests
0	32	17
1	9	3
2	5	5
3	2	5
4	1	5
Total	49	35

*$\chi^2 = 10.11$, $P \leq 0.05$, df = 4.0 (for combined 1977, 1978 and 1979 data using first nesting attempts only).

There were 4.32 ± 3.13 and 4.61 ± 2.48 potential nesting sites available per occupied (N=69) and unoccupied (N=19) loon territories respectively. This difference was not significant (Mann-Whitney u-test). However, there were significantly fewer ($P<0.01$) potential nesting sites available on occupied territories without nests (N=12; 3.17 ± 0.60) than on those with nests (N=57; 4.91 ± 2.62) (Mann-Whitney u-test). These results deal only with lakes having one potential loon territory, as it was often difficult to delineate their boundaries accurately on lakes with more than one.

A chi-square test of the null hypothesis that development within 150 m of a potential site does not influence its selection indicated that fewer nests were located in areas with development than would have been by random

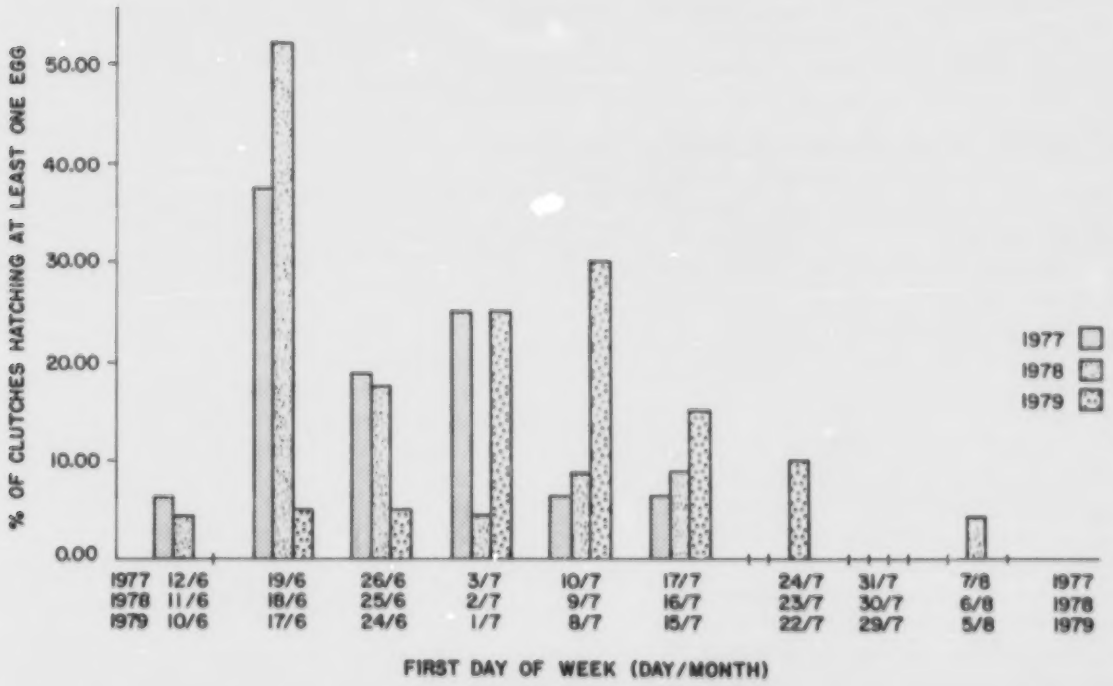


Figure 4.3 Date of initiation of incubation (data from 1977, 1978, and 1979 combined).

Table 4.4 Occupied loon territories with nests*.

No. of Cottages Within 150 m	No. Potential Nest Sites	No. of Nests	No. Nests/ Potential Nest Site
0	160	40	0.25
1	59	14	0.24
2	11	6	0.55
3	4	6	0.67
4	14	6	0.43
5	9	0	0
6	10	0	0
7	3	0	0
8	5	0	0
9	3	0	0
10	2	1	0.50
Total	280	73	

* n = 57 territories; data combined for 1977, 1978 and 1979

selection ($P<0.01$; $x^2=9.86$; df=1) (Table 4.4). Hatching success declined as cottage development increased (Fig. 4.4). The difference between hatching success where there was no cottage development within 150 m and that located where there were more than two cottages within 150 m was significant ($P<0.05$; $x^2=4.92$; df=1).

In areas that ranged from totally undeveloped to moderately developed (up to two cottages within 150 m of the nest), 0.74 chicks per egg hatched survived to the fledgling stage. However, in areas with more than two cottages within 150 m of the nest, 0.90 chicks per egg hatched survived to the fledgling stage.

The weighted activities that occur within 150 m of a nest are listed in Table 4.5. There was a significantly more ($P<0.01$) total activity around developed nests. There was also a greater number ($P<0.05$) of motorboats, non-motorized water craft, and people on shore (Mann-Whitney u-test).

Table 4.5 Comparison of weighted cottage activity within 150 m of eight developed and eight undeveloped Common Loon nests in 1979.

	Average Activity* in Four Visits	
Activities	Developed Nest	Undeveloped Nest
Total activity	81.6	7.2
Large Motorboats	14.9	0.0
Non-Motorized Water Craft	16.0	1.3
People on Shore	28.4	0.0
Swimmers	0.8	0.0
Fishermen	8.6	0.0
Small Motorboats	12.9	5.9

* Units described in methods.

Table 4.6 summarizes the PCA of successful and unsuccessful nests. The first principal component was highly correlated with the upper foliage board measurements, shrub height, and cover provided by mountain holly *(Nemopanthus mucronatus)*. The second was positively correlated with the lower foliage board measurements, ground volume, and height of the ground layer. It was also negatively correlated with exposure to view. The third component was positively correlated with the amount of water near the nest and floating vegetation, but negatively correlated with the horizontal distance from the nest to the water.

Table 4.6 Principal component analysis of successful and unsuccessful Common Loon nests.

	Component Number		
	I	II	III
Description of Variance Associated with each Component	shrub cover	ground volume at nest	nest location
Eigenvalue	9.9	7.1	3.8
% Total Variance Accounted for	23.2	16.5	8.7
Cumulative % of Total Variance Accounted for	23.2	39.7	48.4

Table 4.7 summarizes the PCA of actual and potential nesting sites. The results were similar to the PCA of successful and unsuccessful nests. The first component was highly correlated with the upper foliage board measurements, mountain holly, and shrub height. The second was positively correlated with ground volume, height of the ground layer, and the lower foliage board measurements, but negatively correlated with exposure to view. The third was positively correlated with floating vegetation, but negatively correlated with the bottom substrate adjacent to the nest.

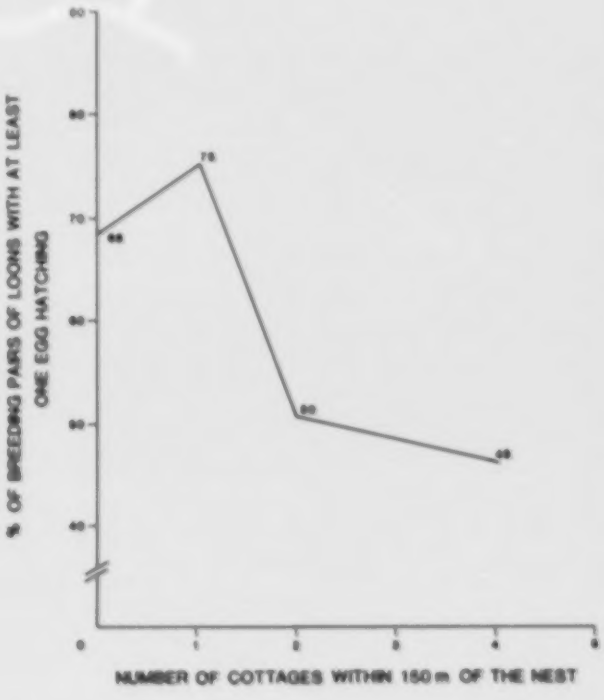


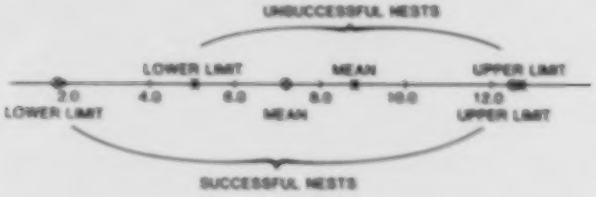
Figure 4.4 Percent of breeding pairs of loons with at least one egg hatching versus development within 150 m of a loon nest.

Table 4.7 Principal component analysis of actual and potential Common Loon nests.

	Component Number		
	I	II	III
Description of Variance Associated with each Component	shrub cover	ground volume at nest	nest location
Eigenvalue	10.2	6.8	3.3
% Total Variance Accounted for	23.1	15.4	7.4
Cumulative % of Total Variance Accounted for	23.1	38.5	45.9

Since the DFA required that the number of variables did not exceed the sample size of the smallest group, the number of vegetative and physical variables (Appendix II) had to be reduced. The variables selected all had eigenvalues greater than 1.0.

The discriminant function axis that illustrates the position of successful and unsuccessful nests is shown in Figure 4.5. Group separation between the two variables of Figure 4.6 was not significant ($P<0.05$; $F=1.54$; $df=2.35$). The group separation was significant ($P<0.01$; $F=5.31$; $df=2.71$) when the first variables were entered.



CLASSIFICATION FUNCTIONS :

UNSUCCESSFUL NESTS = -10.23118+0.39781 (FLVEG)+
0.20061 (SFBG)

SUCCESSFUL NESTS = -8.59154+0.71758 (FLVEG)+
0.17839 (SFBG)

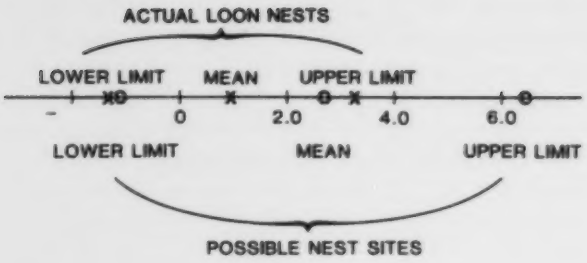
LEGEND
O - SUCCESSFUL NESTS
X - UNSUCCESSFUL NESTS
VARIABLE DEFINITIONS IN APP. II

Figure 4.5 Discriminant function axis with successful and unsuccessful loon nests.

4.5 DISCUSSION

The reproductive success of the Common Loon was consistent over the three year period. Despite a smaller percentage of eggs hatched in 1979, a higher percentage of chicks fledged than in the previous two years. This could have been partly due to the smaller clutch sizes of that year. Studies of the Red-throated *(Gavia stellata)* and Arctic Loons have shown that, when available food is limited, a pair can more readily rear one chick than two to the fledgling stage (Davis 1972).

We found that successful nests had significantly more two egg clutches. This compared favourably with the findings of Titus (1979) which indicated that two egg nests were considerably more successful than one egg nests. One egg



CLASSIFICATION FUNCTIONS :

ACTUAL LOON NESTS = -2.36183+1.67131 (SUBST)+
0.05000 (LEA)

POSSIBLE NEST SITES = -4.00158+2.30299 (SUBST)+
0.08331 (LEA)

LEGEND
O - POSSIBLE NESTS SITES
X - ACTUAL LOON NESTS
VARIABLE DEFINITIONS IN APP. II

Figure 4.6 Discriminant function axis with actual loon nests and possible nesting sites.

clutches are more readily abandoned by loons, and thereby, exposed to predation (Olson and Marshall 1952).

There were significantly fewer eggs in successful clutches in 1979 than in the other two years. The reason for this has not been ascertained. The adult loons might not have been in top breeding condition perhaps due to pesticides and/or heavy metals (Euler, unpublished data 1982). Four of the one egg clutches of 1979 were subsequent nesting attempts which may suggest that the energy reserves of the female were becoming depleted. The findings of Titus (1979) support this theory. In both studies, it was found that there were substantially more ($P<0.05$) one egg clutches in subsequent nesting attempts.

The percentage of chicks at the fledgling stage during the first two years was similar to the figure of 78 percent reported by Olson and Marshall (1952) in Minnesota, but less than the 94.4 percent observed by McIntyre (1975) in the same state. The 1979 results were close to the 88.4 per cent reported by Sutcliffe (1978) in New Hampshire. The number of chicks at this stage per pair of loons with at least one hatched egg compares favourably with the 1.2 (Olson and Marshall 1952), 1.4 (McIntyre 1975), and 1.5 (Sutcliffe 1978).

Most loons in Ontario initiate incubation near the end of May. In 1979, the onset of incubation was delayed due to high water levels which inundated a number of nesting sites used successfully in the two previous years. This occurrence and the human disturbance around the nests probably accounted for the high failure rate of nests early in that breeding season.

Nests initiated after the third week of June were usually not successful. The eggs in these nests were due to hatch after July 1st when the risk of human disturbance was much greater

due to the influx of people on holiday. Eggs in the late stages of incubation may have hatched in spite of this increase in human activity. Attention to the nest intensifies as incubation progresses (Olson and Marshall 1952) which could partly explain the success of some of the subsequent nesting attempts.

Some of the successful nests within 150 m of two or more cottages may have belonged to loons which, over a number of years, have gradually become accustomed to increased human activity. For example, despite the high level of cottage development around a Dickie Lake nest (four cottages within 150 m), the loons reared two chicks to the fledgling stage in both 1978 and 1979. The incubating loons did not flush from the nest even when approached quite closely by canoe. Furthermore, the offspring of these loons exhibited the same lack of fear of humans as their parents. These loons may nest successfully on highly developed lakes, whereas loons with little or no prior exposure to human activity would fail to nest or even to occupy the territory. This is supported by observation that loons on remote lakes are more shy.

Loons nesting in the more secluded parts of the lake, where the risk of human disturbance was reduced, were highly successful. Nests located over 400 m from the nearest cottage tended to be successful, whereas those closer to cottages were significantly less successful. We observed that nests were usually built in more secluded, undisturbed areas of the territory. This may have been related to the number of possible nesting sites available. Territories with many potential sites were more likely to have one or more of them located more than 250 m from the nearest cottage.

Fledgling success was similar to hatching success. If the eggs hatched, there was a good chance that the chick would survive to the fledgling stage regardless of cottage development around the nest. This was probably due to the fact that chicks leave the nest shortly after hatching. Adult loons often move their broods away from the nest to another undisturbed part of the territory. During the three field seasons of this study, few chicks were lost. Since lakes were sampled once every two weeks, the impact of human activity on loon chicks during the critical first two weeks of life could not be assessed. Loon chicks, one week old, require approximately 40 percent of their body weight in food each day. Harassment by people rapidly increases the amount required and also prevents their feeding. Stressed chicks quickly become wet, losing their insulation. They also refuse to eat for prolonged periods of time. Death can occur under these circumstances (Barr 1973).

Of the five successful nests around which human disturbance was studied, two were located in areas with high development levels. In both cases, it was probable that these loons were habituated to human activity. Furthermore, on these lakes, the cottage owners had attempted to minimize their traffic near the nest.

Because loon nests are usually located very close to the water's edge, the nest must be sheltered from wind and waves. However, during the course of this study, exposure to view did not appear to be a critical determinant of site selection. Some lateral cover was desirable, but complete lateral and overhead cover was not necessary. Olson and Marshall (1952) had similar findings in Minnesota. The results of the PCA of successful and unsuccessful nests and of actual and potential nesting sites were very similar. The first two components reflected that, although canopy cover was unimportant, some shrub and ground cover was desirable.

The only difference in PCA results was found in the third component. For succesful and unsuccessful nests, it was negatively correlated with the horizontal distance from the water, but for actual and potential nesting sites, it was negatively correlated with the bottom substrate. The DFA also showed that bottom substrate was an important factor that distinguished actual from possible sites.

The DFA revealed that there was no significant distinction between the measured vegetative and physical components of the habitat near successful and unsuccessful loon nests. This suggests that some other factor like predator populations on the lake determined nesting success. We believe that human disturbance had an important effect on the success rate of loon nests on many of the study lakes.

The DFA of actual and potential nesting sites showed an important difference between the two. More actual nests were located in areas with mucky bottoms. The difference in bottom substrate may have been related to slope. Generally, lakes with mucky or sandy bottoms sloped off gradually into deeper water. The shoreline also tended to have steeper inclines. The shoreline was often such that a loon would have had greater difficulty in reaching a nest. Olson and Marshall (1952) and McIntyre (1975) have indicated that loons cannot use steeply inclining shorelines for nesting.

Leatherleaf *(Chamaedaphne calyculata)* was also an important distinguishing factor between an actual and potential nesting site. The latter had a greater portion of subplot 1 (Fig. 4.2) covered by leatherleaf than did actual nests. Since loons have difficulty moving on land due to the position of their legs, dense and woody vegetation could impede the clearing process that initiates nest construction.

The long-term effect of cottage development on loon reproductive success appears to be negative. The more development, the more reproductive success is reduced. Because loons have a very long lifespan, the impact of the reduction may not be apparent for several years.

4.6 ACKNOWLEDGEMENTS

A special word of thanks is extended to Brian Ratcliff and Mark Sobchuk for their enthusiastic assistance with the summer field work.

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APPENDIX I. PARAMETERS MEASURED AT ACTUAL LOON NESTS AND AT POTENTIAL NEST SITES

Loon nest territory code or possible nesting site code year
Nest attempt*
Successful?* (unsuccessful nest) or date established (successful nest)
Location (bog, island, mainland)
Area of island or bog hummock (sq. m)
Distance to nearest cottage (m)
Aspect
Horizontal distance (cm) to water
Vertical distance (cm) to water
Water depth (cm) adjacent to nest
Distance (m) until water 1 m deep
Water depth (m) 3-1/2 m from shore
Bottom substrate (ooze & muck; sand & gravel; large boulders; solid ledge)
Exposure to waves (1 to 5: completely sheltered to completely exposed)
Exposure to view (1 to 5: completely concealed to completely exposed)
Diam. of nest pad* (cm)
Ht. of nest pad* (cm)
Depth of nest pad* (cm)
Submergent vegetation (0 to 3: absent to dense)
Floating vegetation (0 to 3: absent to dense)
Emergent vegetation (0 to 3: absent to dense)
Percent ground coverage at the nest
Percent water at the nest
Percent rock at the nest
Percent deadwood at the nest
Sum of the percent ground coverage in the remaining 4 plots
Sum of the percent water coverage in the remaining 4 plots
Sum of the percent rock coverage in the remaining 4 plots
Sum of the percent deadwood in the remaining 4 plots
Percent ground volume at the nest
Sum of the percent ground volume in the remaining 4 plots
Percent shrub coverage at the nest
Sum of the percent shrub coverage in the remaining 4 plots
Percent tree coverage at the nest
Sum of the percent tree coverage in the remaining 4 plots
Ht. (cm) of the ground layer at the nest#
Sum of the ht. (cm) of the ground layer in the remaining 4 plots
Ht. (m) of the shrub layer at the nest#
Sum of the ht. (m) of the shrub layer in the remaining 4 plots
Shoreline foliage board (percent cover of each of 6 square from bottom to top)
Backshore foliage board (percent cover of each of 6 squares from bottom to top)
Percent coverage of individual ground species: at the nest and in remaining 4 plots (61 species found)
Percent coverage of individual shrub species: at the nest and in remaining 4 plots (8 species found)
Percent coverage of individual tree species: at the nest and in remaining 4 plots (10 species found)

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*These parameters not measured for possible nest sites.
#Ground layer 0 - 1.4 m
Shrub layer 1.5 - 9.0 m
Tree layer >9.0 m

APPENDIX II. VARIABLES USED IN PRINCIPAL COMPONENT AND DISCRIMINANT FUNCTION ANALYSES

SUCCESSFUL AND UNSUCCESSFUL NESTS

Aspect of runway (ASP)
Horizontal distance from water (cm) (HDIST)
Water depth adjacent to nest (cm) (DEP)
Water depth 3.5 m from nest (D35DEP)
Exposure to view (1 to 5: completely concealed to completely exposed) (VIEW)
Floating vegetation (0 to 3: absent to dense) (FLVEG)
Percent water at nest (PCWAT)
Sum of percent ground volume in remaining 4 plots (PCGVOL)
Shoreline foliage board (percent cover of each of 6 squares from bottom to top - Foliage board is 2 m long; each square is 0.33 m long and 0.33 m wide - square number 1 (SFB1)
Shoreline foliage board - square number 5 (SFB5)
Percent grass *(Gramineae)* cover at nest (GRA)
Sum of percent grass cover in remaining 4 plots (SGRA)
Sum of percent leatherleaf *(Chamaedaphne calyculata)* cover at nest (SLEA)
Area of island or bog (m^2) (AREA)
Vertical distance from water (cm) (VDIST)
Water depth adjacent to nest (cm) (DEP)
Water depth 3.5 m from nest (D35DEP)
Substrate (ooze and muck, sand and gravel, large boulders, solid ledge) (SUBST)
VIEW
FLVEG
PCGVOL
Shoreline foliage board - square number 5
Backshore foliage board (percent cover of each of 6 squares from bottom to top) - square number 1 (BFB1)
SGRA
Percent leatherleaf cover at nest (LEA)
Sum of percent sweet gale *(Myrica gale)* in remaining 4 plots (SSGA)

5. HABITAT SELECTION WITHIN FOUR PASSERINE FAMILIES IN CENTRAL ONTARIO

E. ARMSTRONG, D. EULER and K. CLARK

5.1 SUMMARY

Fifteen common passerines belonging to four families (Tyrannidae, Turdidae, Parulidae and Fringillidae) were studied on cottaged and uncottaged forested shorelines using quantitative habitat measurements and multivariate statistical analysis techniques. Relative differences in coniferous composition and foliage volume were important habitat descriptors in all four families. Flycatcher habitats were distinguished by a range of vegetative diversity while numbers of trees, large trees and shrub snags differed among thrush habitats and total numbers of trees and numbers of small trees aided in distinguishing warbler habitats. All species within each family exhibited significantly different habitat characteristics, except for some warblers. Results are discussed in relation to habitat selection and cottage development.

5.2 INTRODUCTION

Avian habitat studies have often focussed on bird communities associated with a particular habitat type (Kendeigh 1945; Martin 1960; Shugart and James 1973). In recent years, because of increasing need for specific ecological data with which to assess the affects of human disturbance on wildlife, more quantitative habitat studies have been needed. Specific information is necessary to assess the suitability of an area for various bird species, and to estimate the impact of various land use activities upon avian community structure. Environmental impact assessments require knowledge of avian community interactions and habitat requirements of individual species.

As shoreline cottage development in central Ontario has increased, so has demand for forested lakeshore tracts. Habitat alterations caused by cottage development may seriously affect the distribution and abundance of some wildlife species, especially those dependent on the lakeshore habitat. This study investigated the patterns of habitat partitioning within four passerine families in order to know how cottage development changed their habitat and community structure. The purpose of this paper was to determine the habitat characteristics that were important to each family.

The four families selected for this analysis were flycatchers (Tyrannidae), thrushes (Turdidae), warblers (Parulidae), and finches (Fringillidae) (Table 5.1). Discriminant function analysis (BMDP7M Dixon 1975) was used to select the habitat variables which maximize the variance among family members. The stepwise DFA selected, one at a time, those variables, which best discriminated among the habitat parameters, and provided an F-matrix to test significance. This subset of variables which provided maximum discrimination was used in the calculation of two canonical variables on which the observations were plotted. These canonical variables represent a quantitative evaluation of habitat features.

Similar studies of avian habitat partitioning have been done in the southern and western United States (James 1971; Whitmore 1975, 1977; Smith 1977) and some research has also been conducted in northeastern parts of North America (Rice 1978; Holmes et al. 1979b). In a related study, we examined the responses of the avian community to varying degrees of cottage development (Clark et al. 1981).

5.3 STUDY AREA

The study area is located in central Ontario within a 60 km radius of Dorset, Ontario (78° 54'W, 45° 15'N). This area lies in the Great Lakes–St. Lawrence Forest Region which is characterized by eastern white pine *(Pinus strobus)*, red

Table 5.1 Passerine Families and Species Studied

Family	Species	No. of Habitat Circles
Flycatchers (Tyrannidae)	Eastern Phoebe *(Syornis phoebe)*	27*
	Least flycatcher *(Empidonax minimus)*	30
	Eastern wood pewee *(Contopus virens)*	18
Thrushes (Turdidae)	American robin *(Turdus migratorius)*	30
	Swainson's thrush *(Catharus ustulata)*	21
	Veery *(Catharus fuscescens)*	30
Wood Warblers (Parulidae)	Black-and-white warbler *(Mniotilta varia)*	30
	Yellow-rumped warbler *(Dendroica coronata)*	30
	Black-throated green warbler *(Dendroica virens)*	30
	Black-throated blue warbler *(Dendroica caearulescens)*	30
	Blackburnian warbler *(Dendroica fusca)*	30
	Ovenbird *(Seiurus aurocapillus)*	30
Finches (Fringillidae)	Rose-breasted grosbeak *(Pheutious ludovicianus)*	30
	White-throated sparrow *(Zonotrichia albicollis)*	30
	Song sparrow *(Melospiza melodia)*	30

*Three circles were placed in each territory.

pine *(P. resinosa)*, eastern hemlock *(Tsuga canadensis)*, and yellow birch *(Betula alleghaniensis)*, as well as some species common to the Deciduous and Boreal Forest Regions such as sugar maple *(Acer saccharum)* and white birch *(Betula papyrifera)* (Hosie 1969). Both coniferous and deciduous shorelines are present. Where coniferous shorelines dominate, they grade into deciduous forests at varying distances from the shoreline.

5.4 METHODS

Seventy-three lakeshore plots, 100-m x 100-m, were chosen with cottage densities ranging from none to the maximum density observed. Other factors, i.e. size of lake, soil type, slope, and aspect were kept as similar as possible. Coniferous, deciduous and mixed wood forests were represented.

Each plot was censused, using the spot map method (Williams 1936) three times between late May and early July of 1977 and 1978, and the singing males mapped on 10-m x 10-m grids within the plots. All census was conducted over a four hour period each morning, beginning no later than 0700 hours.

Territories were identified from consistent location of singing males, and nest locations. For each of the 15 species studies 6 to 10 territories were randomly selected (Table 5.1). Three singing posts were chosen for habitat analysis within each territory. Habitat measurements were taken between mid July and late August of both years, following the methodology of James (1971). The radius of the habitat circle was 11.3 m. The 22 habitat variables measured were: canopy height (m), number of shrub species, number of shrub individuals (d.b.h. < 8 cm), number of shrub snags, percent conifer composition (shrubs), number of tree species, number of tree individuals, number of tree snags, percent conifer composition (trees), number of class I to class V trees (from 8 – 16 cm to >40 cm), ground coverage sum, shrub coverage sum, tree coverage sum, ground, shrub and tree volume (average %), total volume, and canopy volume (canopy height x tree volume). Ten 1-m^2 quadrats were chosen according to random compass direction and distance from the centre of the plot. The percent volume of foliage was estimated, and on all four corners of each of 10 quadrats the presence of foliage was recorded for three layers: ground (0 – 1.5 m), shrub (1.5 – 9.0

Table 5.2 Habitat variables considered in the discriminant function analysis of species singing posts within four passerine families.

Habitat Variable
Canopy height (m)
Number of shrub species
Number of shrub individuals (d.b.h. 8 cm)
Number of shrub snags
Percent conifer composition of shrubs
Number of tree species
Number of tree individuals
Number of tree snags
Percent conifer compositioon of trees
Number of class I trees (8–16 cm d.b.h.)
Number of class II trees (16–24 cm d.b.h.)
Number of class III trees (24–32 cm d.b.h.)
Number of class IV trees (32–40 cm d.b.h.)
Number of class V trees (>40 cm d.b.h.)
Sum of ground coverage for all quadrats
Sum of shrub coverage for all quadrats
Sum of tree coverage for all quadrats
Ground Volume - (averge ground volume for all quadrats (%))
Shrub Volume - (average shrub volume for all quadrats (%))
Tree Volume - (average tree volume for all quadrats (%))
Canopy Volume (canopy height x tree volume 10)

Table 5.3 Matrix of F values for separation of each species centroid from other species centroid.

Family	Degrees of Freedom	Species Matrix - F Values					
Tyrannidae	4, 69		Least Flycatcher	Eastern Phoebe			
		Eastern Phoebe	17.27*				
		Eastern Wood Pewee	4.51*	16.18*			
Turdidae	5, 74		Veery	American Robin			
		American Robin	7.98*				
		Swainson's Thrush	17.79*	30.40*			
Parulidae	5, 170		Ovenbird	Black-throated Green Warbler	Blackburnian Warbler	Yellow-rumped Warbler	Black-throated Blue Warbler
		Black-throated Green Warbler	0.61				
		Blackburnian Warbler	2.39*	2.63*			
		Yellow-rumped Warbler	7.39*	6.54*	8.86*		
		Black-throated Blue Warbler	7.75*	4.65*	11.58*	6.43*	
		Black-and-white Warbler	12.40*	10.87*	13.44*	1.77*	9.411*
Fringillidae	3, 85		Rose-breasted Grosbeak	Song Sparrow			
		Song Sparrow	17.75*				
		White-throated Sparrow	12.19*	6.28*			

*F-values significant at p 0.05

m), and tree (>9.0 m) (Willson 1974). The proportion of species observed in each of 4 general locations (ground, shrub, coniferous tree, deciduous tree) was recorded during the lot censuses and compared.

5.5 RESULTS

Results of the 4 discriminant function analyses are presented in Table 5.2. Coniferous composition of trees was selected in 3 of the DFA's, and coniferous composition of shrubs was selected in the fourth family (Turdidae). Some aspect of vegetation volume was important in discriminating habitats within each family (Tyrannidae – tree, Turdidae and Parulidae – ground, Fringillidae – canopy). Other important variables selected in one or more DFA's were number of trees in one or more size classes, number of shrub snags, and number of tree and shrub species.

The 2-dimensional relationships among habitat relationships of the 4 families are shown in Figures 5.1 to 5.4. While the discriminant function axes are comprised of several variables, one of the major components of each axis is also presented.

All species within each family had significantly different habitat relationships according to the constructed discriminant functions, except for the ovenbird and the black-throated green warbler and the yellow-rumped and black-and-white warblers (Table 5.3).

The proportion of observation of each species in the 4 general locations is shown in Figure 5.5. For Parulids the relationship between the percentage composition of the singing post area and the percentage of observations in coniferous trees is shown in Figure 5.6.

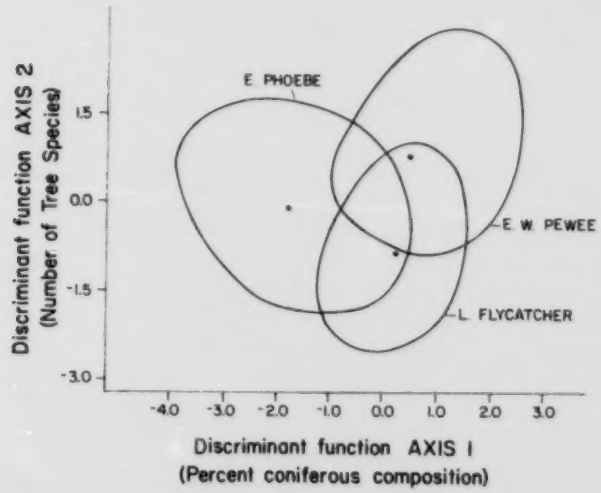

Figure 5.1 Two dimensional ordination of flycatcher habitat according to 2 discriminant function axes. Solid circles indicate mean values; lines delimit range of values.

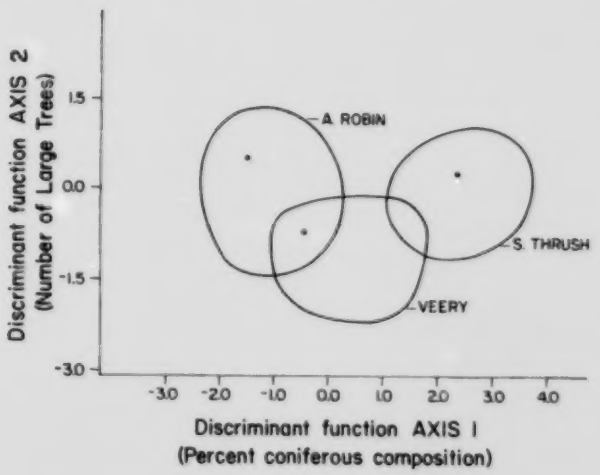

Figure 5.2 Two dimensional ordination of thrush habitat according to 2 discriminant function axes. Solid circles indicate mean values; lines delimit range of values.

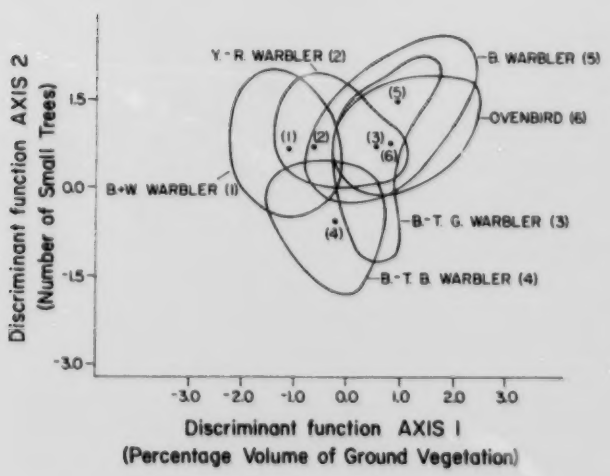

Figure 5.3 Two dimensional ordination of warbler habitat according to 2 discriminant function axes. Solid circles indicate mean values; lines delimit range of values; numbers associate species with means.

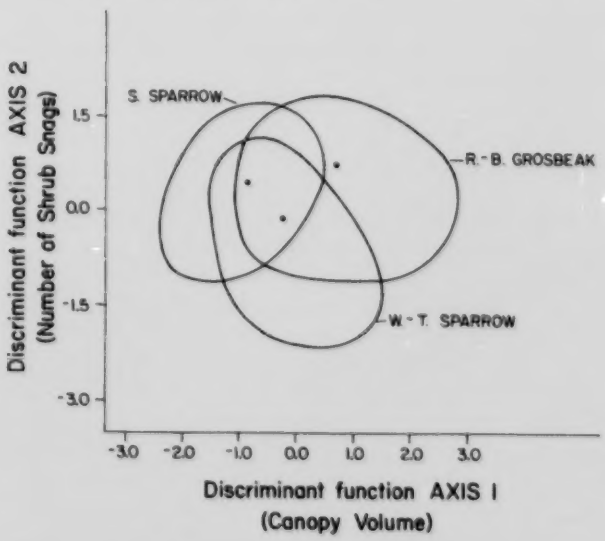

Figure 5.4 Two dimensional ordination of finch habitat according to 2 discriminant functions. Solid circles indicate mean values; lines delimit range of values.

5.6 DISCUSSION

The 4 passerine families studied appear to partition habitat resources according to different (with few similarities) habitat characteristics found within the lakeshore forest. The percent coniferous composition of trees was important in differentiating habitats for all families except thrushes, where percent coniferous composition of the shrub layer was important. As well, some aspect of vegetation volume was important in discriminating between habitats selected by species of all four families.

Tree characteristics and vegetative diversity were important in flycatcher habitat separation. Pewees were generally found in areas with fewer species of woody plants than phoebes and least flycatchers. Pewees and least flycatchers were characteristic of deep-canopied, closed, deciduous forests, although the latter species often bred along deciduous

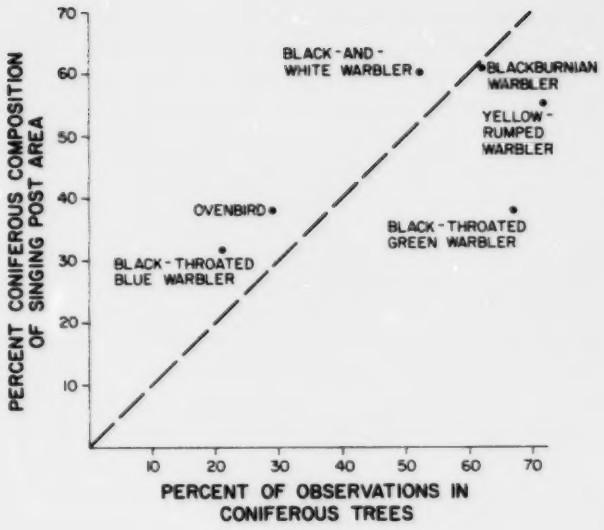

Figure 5.6 Relationship between percent coniferous composition of warbler habitat and coniferous tree usage.

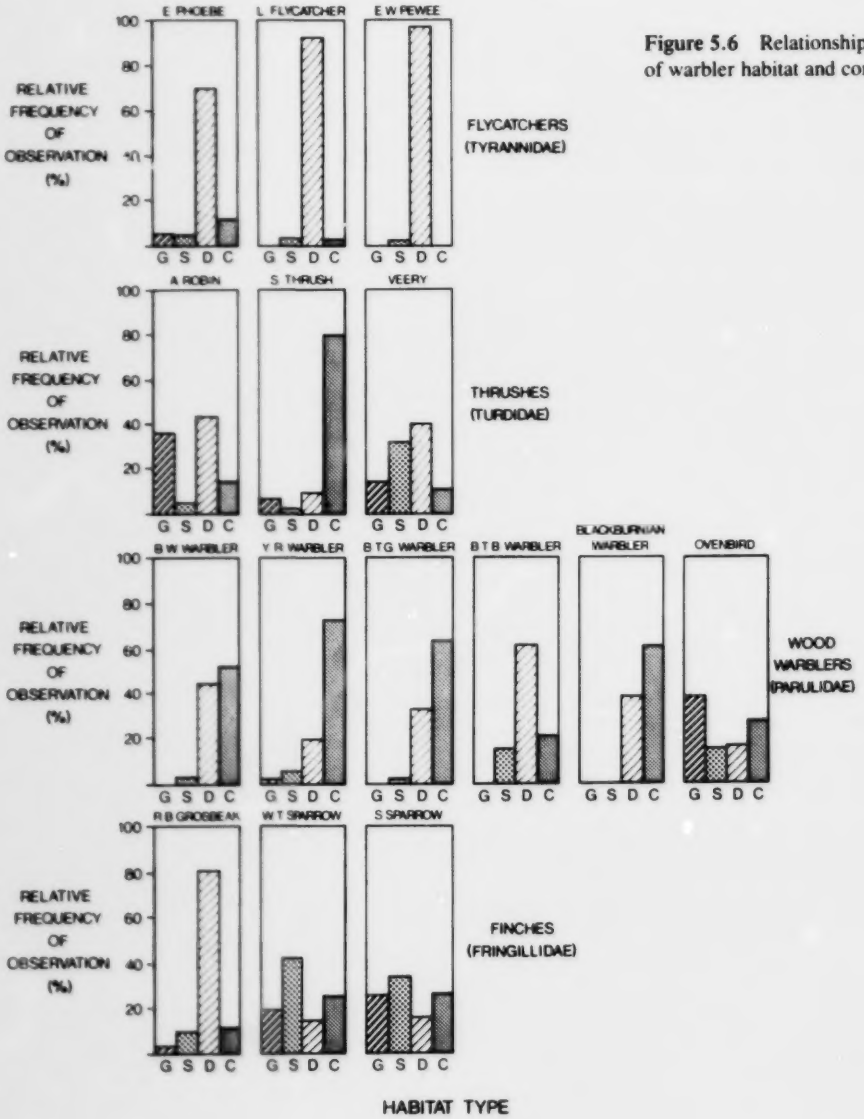

Figure 5.5 Relative frequency of observation of 15 species of woodland birds in 4 vegetative types: ground vegetation (G), shrub vegetation (S), deciduous trees (D) and coniferous trees (C).

shorelines while pewees were uncommon near the shore and were typically found in relatively homogeneous upland deciduous forests. Tree species diversity tended to be greatest near the shore and decreased with distance from the shore, perhaps in response to a moisture gradient (Racey et al. 1981). The significance of the number of woody species as discriminating variables may thus reflect differential responses of the three flycatcher species to the moisture gradient, previously shown to be of value in avian habitat selection (Smith 1977). The phoebe was the only flycatcher that used coniferous trees to any extent, and the inclusion of conifer composition as a discriminating variable separated habitats of this species from those of least flycatchers and wood pewees. The number of tree species decreased with development only on coniferous plots (Clark et al. 1981), illustrating the interrelationships between conifer composition and tree species diversity. The latter two species were almost always observed in deciduous trees. Pewees have been observed elsewhere to frequent mixed and coniferous forest (Hespenheide 1971b; Shugart and James 1973) suggesting considerable diversity in habitat selection throughout their range.

The volume of vegetation in the tree layer separated phoebe habitats with the lowest volumes from wood pewee and least flycatcher habitats with the progressively increasing volume. Hespenheide (1971b) also found that least flycatchers were found in more dense forests than wood pewees, although Johnston (1971) reported the reverse situation in a modified deciduous forest in Virginia. When found in areas with a dense canopy, least flycatchers forage at mid heights where the foliage is more open (Breckenridge 1956, Holmes et al. 1979a; Sherry 1979) suggesting that open foraging sites may be the key factor that is being selected for. Phoebes were restricted in their breeding habitat to man-made clearings in the forest which have low vegetative volumes in the tree layer (Clark et al. 1981). In central Ontario their territory requirements appear to include open forest habitat for foraging and perching sites, and buildings for nest sites. Phoebes population respond positively to reduced vegetation along streambanks (Possardt and Dodge 1978). This species seems almost entirely restricted to nesting on man-made structures (Johnston 1971; Harrison 1975), and has accordingly responded positively to the increase in cottage development in central Ontario (Clark et al. 1981).

Interspecific interactions may also be involved in flycatcher habitat usage, as the least flycatcher is socially dominant over other small forest birds (Sherry 1979). Flycatcher habitat separation appears to be based upon food supply and the potential for competition for food resources by similar sized species (Hespenheide 1971a).

Breeding habitats of the 3 thrush species were best separated by habitat variables reflecting forest type, forest maturity and degree of cottage development: percent conifer composition (shrubs), number of large trees (class IV) ground volume, number of shrub snags and number of trees. In the study area Swainson's thrushes typically inhabit undeveloped densely treed, mature coniferous forests with a coniferous understory (Dilger 1956). At the other extreme, robins are dependent upon the open habitat conditions created by road buildings and cottage development, including a reduced number of trees and reduced ground volume (Clark et al. 1981). Robins were on the ground, where they were usually foraging, in 37% of all observations. Similar sites are used elsewhere (Williamson 1974; Thomas et al. 1977). Young coniferous stands contain a much greater density of trees than deciduous stands, and as they mature, there is a large increase in the number of snags (Young et al. 1979). The habitat gradient from Swainson's thrushes to robins represents both the gradient from coniferous to mixed or deciduous under-storied forests, and the gradient from uncottaged to cottaged shorelines.

Both the robin and Swainson's thrush frequent habitats with low ground volumes, the former because the original ground vegetation has been replaced by lawns, and the latter because of acidic soils and reduced light penetration in coniferous forests. Veeries select habitats with dense ground volumes, indicative of moist early successional forests with a dense understory, and the edges of some cottaged areas where light penetration and lack of active maintenance have produced dense ground and shrub vegetation. Undisturbed habitats do not usually contain a dense enough understory for this species (Dilger 1956). Shrub coverage values, reflecting both moisture conditions and successional stage, are effective in separating veery and wood thrush *(Hylocichla mustelina)* habitats (Bertin 1977). Of the 3 thrushes studied, the veery was the only one to use shrubs to any extent (32% of all observations).

The Swainson's thrush appears restricted to the coniferous forest. Eighty percent of the observations of this species were in coniferous trees, much more than either of the other thrush species. Swainson's thrushes will frequent deciduous forests outside the range limits of the veery, suggesting that interspecific competition may affect habitat relationships between the two species (Erskin 1977).

Wood warbler habitat separation was poor even when all DFA variables were included, indicating a great deal of habitat overlap. Discriminant function analysis of territories of 4 warbler species in Algonquin Park revealed similar habitat characteristics were of value in habitat separation: coniferous composition (trees), % canopy, number of deciduous shrubs, and number of trees less than 30 m high (McLaren 1975). Although all six species used coniferous and deciduous trees in our study, the relative proportions varied considerably. The habitats of the six warblers could be roughly grouped as moderately coniferous (black-throated blue, ovenbird, black-throated green) and heavily coniferous (black and white, blackburnian, yellow-rumped). Four of the species used conifer trees approximately according to their abundance, while the yellow-rumped and black-throated green warblers selected for conifer trees. The black-throated green warbler used conifer trees almost twice as much as the average plot occurrence. This indicates one manner in which this species may reduce competition with the ovenbird and black-throated blue warblers, all of which occur in similar forest types.

The number of trees differentiated black and white warbler habitat (high numbers) and blackburnian warbler habitat (low numbers) from habitats of other warbler species. This discrepancy between the former two species, given the very similar trends in coniferous composition and usage data highlights a major variable in habitat separation. Black and white warblers are more common in younger conifer forests with a large number of small trees while blackburnian warblers are more common in more mature conifer forests.

Black and white warblers respond similarly to size of trees in pole hardwood stands in Virginia (Crawford et al. 1981). There, ovenbirds were shown to be a "closed canopy obligatory species", while black and white warblers were a species whose habitat was skewed towards a closed canopy (Crawford et al. 1981). In various seral stages following clear-cutting the 6 warbler species included in our study were found in mid to late seral stages 3 (black-and-white warbler), 4 (ovenbird, black-throated blue warbler, black-throated green warbler) and 5 (blackburnian warbler, yellow-rumped warbler) (Titterington 1979).

The inclusion of ground vegetation volume in the discriminant function serves primarily to separate habitats of the black-throated blue warbler, most forest conditions with a dense ground layer, from other warbler habitats. This layer of vegetation, critical for this species, is used for foraging, singing and nest sites. The black-throated blue warbler has a patchy distribution, occurring specifically in areas with high density understory foliage (Holmes et al. 1979).

Much of the overlap observed in the discriminant function resulted from trying to separate all six warbler habitats simultaneously. Each variable entered in the discriminant function was of value in separating habitats of at least some of the species, but some of this separation was masked when all variables and all species were combined. Other factors besides general habitat characteristics may also be important in niche separation within the Parulidae. Fifteen warbler species have been recorded breeding in central Ontario during the course of this study. Tree height profiles, foraging strategies, tree species preferences and within-tree-location preferences are all important in niche differentiation (McArthur 1958; Franzreb 1976; Franzreb 1978; Sherry 1979). In Algonquin Park, foraging behaviour characteristics were more capable of correctly clarifying warbler species than were forest composition of physiognomic characteristics (McLaren 1975).

Interactions could also play a role. Black-throated green warblers exhibit a high degree of habitat stereotype, and are socially dominant to the yellow-rumped warbler which shows ecological release in the absence of the former species (Morse 1976). The yellow-rumped is a habitat generalist which can adapt to varying environmental conditions in areas not occupied by other warbler species, including natural logged areas (McArthur 1958; Morse 1976; Franzreb 1978). This would explain the common occurrence of yellow-rumped warblers even on highly developed but coniferous cottaged areas, whereas black-throated green warblers and cottage development were often mutually exclusive (Clark et al. 1981). No warblers studied responded positively to cottage development, with responses being either negative or neutral. Although habitat characteristics of the chestnut-sided *(Dendroica pensylvanica)* and American redstart *(Setophaga ruticilla)* were not studied, they appeared to respond positively to the dense edge vegetation resulting from road and transmission line construction. Elsewhere in central Ontario their preferred habitat was characterized by large numbers of shrubs and small trees (McLaren 1975).

The habitats of the three finches were best separated by a discriminant function based on canopy volume, number of shrub snags and percent conifer composition of trees. The rose-breasted grosbeak was the only one of the three to actually breed in forested areas with high canopy volumes and the only species to use deciduous trees to any extent. It nested in the mid-successional deciduous forests with a dense shrub layer as well as in dense deciduous "islands" adjoining cottage areas. It occurs in areas with a high number of shrub snags. In seral stages following clearcutting in Maine, rose-breasted grosbeaks were typical of the mid-to-late seral stage 4 and were associated with increased densities of hardwood regeneration greater than 4.5 mm high and trees with dbh 10-15 cm (Titterington et al. 1979). The song sparrow was most common in cottaged deciduous or mixed forest habitats, where a large number of snags and a large number of trees have been removed, thereby lowering the canopy volume (Clark et al. 1981). This species also occupies territories along lakeshores in uncottaged forests, where low canopy volume resulted because up to half of the circle around a singing post fell over the water. The intermediate position of the white-throated sparrow reflects its occurrence in two habitat types: lowland coniferous swamps with an open, low-volume canopy layer and a large number of shrub snags, and along the edge of cottaged areas. White-throated sparrows respond positively to logging operations in northern hardwood forests (Webb et al. 1977), and are typical of vegetation conditions 3-12 years after cutting (Titterington et al. 1979). The habitat characteristics and pattern of habitat use are quite similar for both sparrow species. These results concur with those of Martin (1960) in Algonquin Park, who found both species avoiding mature, closed-canopy coniferous forests in favour of the more open bogs. The song sparrow is also common in urban situations, where open areas with a relatively open shrub and herbaceous layer are preferred (Thomas et al. 1977).

The knowledge of comparative habitat descriptors for a number of bird species not only increases the understanding of competitive ecology but aids in the management of sympatric species. Since cottage development alters shoreline vegetation in a predictable manner it is possible to use detailed descriptions of avian habitat to evaluate the response of bird species to shoreline development (see Clark et al. 1981). By altering the successional stage of a forest and maintaining it at the new stage, cottagers have the potential to directly influence the avian species in the adjacent forest.

5.7 ACKNOWLEDGEMENTS

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6. REPRODUCTIVE ECOLOGY AND HABITAT USAGE OF WOODLAND BUTEOS IN CENTRAL ONTARIO

E. ARMSTRONG and D. EULER

6.1 SUMMARY

Habitat use by Broad-winged Hawks *(Buteo platypterus)* and Red-shouldered Hawks *(B. lineatus)* was compared from 1977 to 1979 in central Ontario to determine how these birds could be affected by shoreline cottage development. The Broad-winged Hawk was the most commonly observed raptor in the study area, followed by the Red-shouldered and the Red-tailed Hawks *(B. jamaicensis)*. Broad-winged Hawk nests were found in younger deciduous-dominated mixed forests, while Red-shouldered Hawk nests were usually located in mature deciduous forests. There were no significant differences between the macrohabitat selection of these two species. Red-shouldered Hawks appear to be more susceptible to disruption of breeding habitat caused by cottage development because of their preference for dense, continuous forest. Broad-winged Hawk territories contained both forested and open areas, the latter used for perching and territorial boundaries. All three of these *Buteos* species appear to occupy mutually exclusive territories, both interspecific and intraspecific.

6.2 INTRODUCTION

In central Ontario, the Red-shouldered Hawk and Broad-winged Hawk breed in similar habitats in the Great Lakes-St. Lawrence forest region. This area is experiencing a high demand for lakeshore and back-shore cottage development (Smith and Mulanootti 1979). Although studies of habitat usage and overlapping territories have been conducted on open-country raptors (Wellar 1964; Schnell 1968), these relationships have rarely been examined for forest-dwelling hawks (Titus and Mosher 1981). These two species do not extend into each other's range throughout much of North America: the Broad-winged breeds in the boreal forest as well as further south, while the Red-shouldered is more restricted to the eastern hardwood forest (Beebe 1974). In Ontario, their ranges have been earlier described as mutually exclusive (Snyder 1949). Across North America, Red-shouldered Hawk populations appear to be declining with the exception of a stable population in upstate New York, while those of the Broad-winged Hawk remain high and stable (Brown 1971; Fyfe 1976; Tate 1981).

As part of the Lakeshore Capacity Study, which examined the impact of shoreline cottage development on wildlife populations and habitat, we compared the habitat usage of these two raptors. Their habitat was assessed and behavioural differences examined. Supplementary data on other hawk species were also recorded.

6.3 STUDY AREA AND METHODS

The study area was located in central Ontario within a 60 km radius of Dorset (78° 54'W, 45° 15N) (Figure 6.1). It lies in the Great Lakes-St. Lawrence forest region, and is characterized by a mixture of coniferous trees such as eastern hemlock *(Tsuga canadensis)*, balsam fir *(Abies balsamea)*, and white pine *(Pinus strobus)*, and deciduous trees such as sugar maple *(Acer saccharum)*, red maple *(A. rubrum)*, white birch *(Betula papyrifera)*, and beech *(Fagus grandifolia)*. Both coniferous and deciduous shorelines are present. Where the former predominate, they grade into deciduous forest at varying distances from the shoreline.

Figure 6.1 The study area.

During field work conducted for other activities between 1977 and 1979, confirmed and possible raptor nests were located. These were monitored for reproductive activity during the spring and early summer beginning in early May. Nesting chronology and presence of nestlings were recorded from ground observations. Nesting success was

evaluated on the basis of the number of young of fledgling age (Postupalsky 1977). The habitat characteristics of the area around the nesting sites were measured after the nesting attempt had been completed.

Studies of the immediate area around the nest (microhabitat) were conducted within circles of 0.04 ha around the nests, following the methodologies of James (1971) and Armstrong et al. (1981). The number of shrubs, shrub species and shrub conifer composition were measured on transects, 1.75 m wide, which crossed the circle. A shrub was defined as any woody species less than 8.0 cm dbh and more than 1.5 m in height. The number, species, diameter class, percent conifer composition, and canopy height were recorded for all trees within the circle. Ten 1-m x 1-m plots were located within the circle at random distances and compass directions from the centre. These plots formed the base of three-dimensional columns within the ground (0-1.5 m), shrub (1.5-9.0 m) and tree (>9 m) layers (Willson 1974). The estimated percentage of volume occupied by foliage in each of the layers was averaged for the 10 plots. These values were summed for the layers to produce a measurement of total vegetation volume. The product of tree volume and canopy height (canopy volume) was calculated. The occurrence of foliage in each corner of the column was also noted and totalled by layer for all plots, giving a maximum estimated cover score of 40. Nest height, tree height, and diameter at breast height of the nest tree were recorded.

Macrohabitat studies were conducted within circles of 3.14 ha (radius of 100 m) around the nesting site. The circle was divided into 10 x 10-m grids and cover-mapped to indicate the area occupied by coniferous and deciduous forest, water, open area, and man-made clearings. The percent slope, aspect, elevation, and distances to the nearest lake, man-made clearing, and water source were recorded. The position of the nest tree on the slope in relation to the nearest body of water (lake position) and the local terrain (valley position) were recorded on a linear scale of 1 (lowland) to 6 (upland plateau). The type of water body closest to the nest was also recorded on a linear scale form 1 (seasonal stream) to 7 (lake). A Development Index (DI) for the nearest 100 m section of lake shoreline was measured as the greatest length cleared within 50 m of the water.

Data for Red-shouldered and Broad-winged Hawk nests were analysed using Discriminant Function Analysis (DFA). This selected the habitat variables that most clearly differentiated the nesting sites of these raptors according to sample variance (James 1971; Armstrong et al. 1981). Microhabitat and macrohabitat measurements were analysed separately to examine habitat selection trends related to the nest site and nesting habitat selection respectively. Where the same nest was used in more than one year, the habitat data were re-entered for each attempt. Micro- and macrohabitat characteristics were similarly measured around known perching sites of the Broad-winged Hawk, and compared with nesting sites by DFA.

Field staff recorded observations of raptors during the breeding season, following a modification of Craighead and Craighead's (1956) technique. Data were recorded for weather, species, time of year, forest type and density, proximity to cottage development, perching site, prey species, and behaviour. Activities recorded included perching, flying, feeding, calling, hunting, interspecific and intraspecific interactions. Frequency analysis was applied to this information. Only broad-winged and red-shouldered hawks were recorded in 1978, but all raptor species were recorded in 1979.

6.4 RESULTS

6.4.1 NESTING CHRONOLOGY

An inventory of 101 potential nests resulted in the documentation of 27 active Broad-winged Hawk nests and nine Red-shouldered Hawk nests. Nest building was observed in early May for the Red-shouldered and from early May through mid-June for the Broad-winged Hawk (Fig. 6.2). Most activity involved garnishing the nests with coniferous twigs. Many nests had been built in a previous year. As nests were only observed from the ground, it was not possible to ascertain the time of hatching. Nestlings of the Red-shouldered Hawk were observed as early as the third week of May, while young Broad-winged Hawks were observed in the second week of June. Fledgings were observed in early July for the Red-shouldered Hawk and from mid to late July for the Broad-winged Hawk.

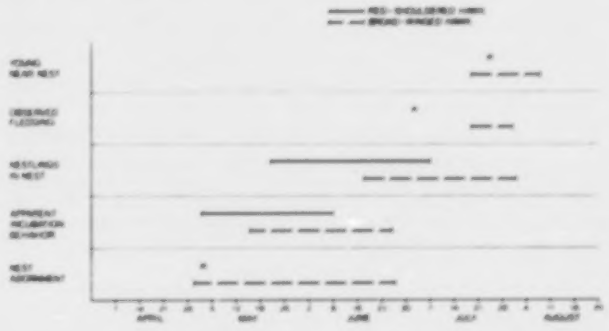

Figure 6.2 Temporal trends in observed nesting activities of broad-winged and red-shouldered hawks from 1977 to 1979. Apparent incubation behaviour may include newly hatched young not visible from the ground. H = Holiday.

6.4.2 HABITAT CHARACTERISTICS

The DFA indicated that the nest microhabitats of these two raptors differed according to four habitat variables: number of trees, ground cover, nest height, and percent tree conifer composition (Table 6.1) ($F = 7.31$, $df = 4.31$, $P<0.05$). This separation characterized Red-shouldered Hawk nesting habitat as mature, open deciduous forest with low ground cover. Broad-winged Hawk habitat was dense, deciduous-dominated, mixed forest with higher ground cover. Some Red-shouldered Hawk nests were located in the latter type of habitat. All Red-shouldered Hawk nests and 88.9% of Broad-winged nests were classified correctly according to these criteria.

Macrohabitat characteristics for nests of these raptors differed only for elevation ($F = 7.93$, $df = 1.35$, $P<0.05$) (Table 6.2). Separation was fair: 86% and 57% of the Broad-winged and Red-shouldered Hawks respectively were correctly classified. When elevation was removed form the analysis because of possible bias in site selection, there were no significant differences in measured macrohabitat variables.

Five microhabitat variables were included in the DFA between Broad-winged Hawk nests and perching sites: number of shrubs, shrub cover and volume, number of large trees, and canopy volume (Table 6.1) ($F = 39.83$, $df = 5.38$, $P < 0.05$). All sites were correctly classified using these variables. Three macrohabitat variables were useful in differentiating nesting and perching sites: area of man-made clearings, distance to clearing, and slope (Table 6.2) ($F = 21.6$, $df = 3.41$, $P < 0.05$). Most sites (88.9%) were classified correctly, using these criteria.

Table 6.1 Microhabitat characteristics (mean ± SD) of Broad-winged and Red-shouldered Hawk nests, and Broad-winged Hawk perching sites.

Habitat Characteristic	Red-shouldered Hawk Nest (9)†	Broad-winged Hawk Nest (27)	Broad-winged Hawk Perching Site (17)
Canopy Height (m)	24.4 ± 3.5	21.0 ± 2.7	11.4 ± 8.9
No. shrub species	2.6 ± 0.7	3.3 ± 1.0	3.8 ± 2.3
No. shrub individuals	22.7 ± 12.8	18.1 ± 12.8**	28.2 ± 25.9
Coniferous shrubs (%)	8.0 ± 12.2	16.3 ± 24.3	11.4 ± 17.3
No. tree species	3.0 ± 1.7	4.8 ± 1.5	2.6 ± 2.1
No. tree individuals	17.7 ± 6.3*	28.6 ± 8.6	13.2 ± 12.1
No. small trees (8-32 cm dbh)	12.0 ± 7.5	24.6 ± 10.0	11.6 ± 11.1
No. large trees (>32 cm dbh)	5.7 ± 2.9	4.0 ± 2.8**	1.5 ± 1.8
Coniferous trees (%)	10.7 ± 13.6*	17.6 ± 22.8	14.4 ± 25.0
Ground cover (0-40)	25.7 ± 9.5*	29.4 ± 5.4	31.7 ± 8.0
Shrub cover (0-40)	26.9 ± 10.4	27.6 ± 6.6**	10.5 ± 10.9
Tree cover (0-40)	37.3 ± 2.3	34.1 ± 4.8	7.1 ± 10.9
Ground volume (%)	16.1 ± 9.2	18.0 ± 6.8**	29.6 ± 14.1
Shrub volume (%)	15.6 ± 6.1	18.1 ± 6.2	8.4 ± 9.4
Tree volume (%)	29.6 ± 7.0	31.4 ± 10.0	4.6 ± 7.3
Canopy volume‡	72.4 ± 20.4	64.9 ± 21.0**	9.9 ± 16.3
Vegetation volume (%)	57.6 ± 12.2	66.6 ± 15.4	41.8 ± 22.6
Nest tree height (m)	23.1 ± 5.2	21.1 ± 2.6	
Nest tree dbh (cm)	48.3 ± 11.6	44.2 ± 16.2	
Nest height (m)	14.0 ± 3.6*	11.8 ± 2.8	

†Sample size.

*Variables included in the discriminant function of Red-shouldered and Broad-winged Hawk nests.

**Variables included in the discriminant function of Broad-winged Hawk nesting and perching sites.

‡Tree volume x canopy height.

The Broad-winged Hawk nested in several species of tree including white birch, yellow birch *(Betuala alleghaniensis)*, and sugar maple (Table 6.3). The Red-shouldered Hawk nested in only three species, primarily yellow birch and american beech.

6.4.3 NESTING SUCCESS

Of the 16 Broad-winged Hawk nests for which either nesting failure or the presence of young near fledgling age were documented, 14 (87.5%) fledged young. Fledging success averaged 1.5 young per nest and 1.7 young per successful nest. The highest number of young fledged per nest was 3. Of six Red-shouldered Hawk nests with documented outcomes, five were successful (83.3%). Fledging success was 1.8 young per nest and 2.2. per successful nest. Highest number of young per nest was also 3. Some nests of both species were not located until young had already hatched. Therefore, some biases may have been introduced to the success rate calculation because early nests with eggs which did not hatch may have been missed (see Mayfield 1961).

6.4.4 RAPTOR OBSERVATIONS

The most commonly seen diurnal raptors were the Broad-winged (355), Red-shouldered (49), and Red-tailed (20) Hawks, the Turkey Vulture *(Cathartes aura)* (18), and the Osprey *(Pandion haliaetus)* (16). Less frequent observations were made of the Goshawk *(Accipter gentilis)* (5), Kestrel *(Falco sparverius)* (4), Marsh Hawk *(Circus cyaneus)* (4), and Sharp-shinned Hawk *(A. straitus)* (2). The Cooper's Hawk *(A. cooperii)* was present in the study area, but sightings were not made in 1979.

A total of 577 Broad-winged and 64 Red-shouldered Hawk observations were made in both years (Table 6.4). Most Broad-winged Hawks were seen during the last half of May, between 1000 and 1300 hours, in deciduous forests with some clearings, along road edges, in uncottaged areas. The most common perching sites were power lines, and most birds were flying or perching when seen. The behaviour of Red-shouldered Hawks was typified as active in early morning (0700-1200) in dense, deciduous forests back from the lakeshore in uncottaged areas. Most perching sites were in deciduous trees. The most commonly observed activities were calling (57.8%), at the nest (32.8%), flying (28.1%), and perching (23.4%).

Significantly more Red-shouldered Hawks were found in dense forests than Broad-winged Hawks, which were more common in forest areas with openings ($x^2 = 66.6$, $df = 1.0$, $P < 0.001$). Greater proportions of Red-shouldered Hawks

Table 6.2 Macrohabitat characteristics (mean ± SD) of Broad-winged and Red-shouldered Hawk nests, and Broad-winged Hawk perching sites.

Habitat Characteristic	Red-shouldered Hawk Nest †(9)	Broad-winged Hawk Nest (27)	Broad-winged Hawk Perching Site (17)
Lake position (1-6)	4.6 ± 1.4	4.2 ± 1.6	3.5 ± 2.1
Valley position (1-6)	3.2 ± 1.3	3.3 ± 1.5	3.2 ± 2.0
Distance to lake (m)	223.9 ± 146.8	215.1 ± 232.1	491.4 ± 357.7
Distance to clearing (m)	27.8 ± 18.2	42.1 ± 30.2**	1.3 ± 2.2
Distance to man-made clearing (m)	137.8 ± 158.3	180.0 ± 301.9	6.0 ± 16.8
Distance to water (m)	62.3 ± 38.5	51.5 ± 30.8	31.3 ± 34.5
Type of water (1-7)	5.1 ± 1.9	4.8 ± 2.0	4.5 ± 1.2
Slope (%)	21.3 ± 11.6	26.7 ± 16.9**	14.4 ± 11.1
Area coniferous forest (100 m^2)	17.9 ± 35.2	35.5 ± 30.3	58.8 ± 54.8
Area water (100 m^2)	40.4 ± 28.5	52.5 ± 40.6	133.2 ± 46.3
Area man-made clearing (100 m^2)	31.6 ± 26.7	26.1 ± 27.7**	89.9 ± 37.3
Shore Dev. Index	0.7 ± 0.7	0.8 ± 0.9	
Sine of aspect	0.4 ± 0.7	-0.1 ± 0.8	0.3 ± 0.8
Cosine of aspect	-0.1 ± 0.7	0.1 ± 0.7	-0.2 ± 0.6
Elevation (m)	295.5 ± 60.9*	350.4 ± 48.8	362.5 ± 24.4

†Sample size.

*Variables included in the discriminant function of Red-shouldered and Broad-winged Hawk nests.

**Variables included in the discriminant function of Broad-winged Hawk nesting and perching sites.

Table 6.3 Nest tree species used by Red-shouldered and Broad-winged Hawk nests.

	Number of Nests	
	Broad-winged Hawk	Red-shouldered Hawk
White birch	7	0
Yellow birch	5	4
Sugar maple	4	1
American beech	0	4
Red oak	3	0
Large-toothed aspen *(Populus grandidentata)*	2	0
White pine	1	0
Trembling aspen *(Populus tremuloides)*	1	0
Eastern hemlock	1	0
Basswood *(Tilia americana)*	1	0
Total	25	9

were also sighted in backshore locations ($x^2 = 21.4$, df = 1.0, $P < 0.001$). Red-shouldered Hawks were more commonly observed in uncottaged than were Broad-winged Hawks ($x^2 = 14.7$, df = 1, $P < 0.001$).

The number of Red-tailed Hawk observations was not sufficient to indicate behavioural patterns. The largest proportion of sightings were made in open or partially open areas (88%). Dead trees and hydro poles were the most common perching sites.

6.4.5 BEHAVIOURAL INTERACTIONS

Many observations of intraspecific and interspecific interactions of Broad-winged Hawks were made. For example, Broad-winged Hawks were seen harassing a Red-tailed Hawk three times (perched adjacent to, calling loudly with attention directed to the latter species). On another occasion a Broad-winged Hawk was harassed by a Red-shouldered Hawk (aerial pursuit and calling). Another time, a perching Red-shouldered Hawk called as a Broad-winged Hawk soared past directly overhead, although it had been silent and furtive during several preceding minutes of observation.

Broad-winged Hawk aerial displays were frequently observed. Often a soaring bird was joined in the air by another. They

Table 6.4 Location and behaviour observations of Broad-winged and Red-shouldered Hawks, 1978-1979 (unknown observations omitted).

	Number of Observations	
	Broad-winged Hawk	Red-shouldered Hawk
Period of Observation		
May 1-15	50	8
May 16-31	118	9
June 1-15	65	7
June 16-30	103	12
July 1-15	82	11
July 16-31	72	9
August 1-15	54	1
August 16-31	29	7
Sept. 1-15	1	0
Time of Observation		
0500-0700	27	3
0701-0900	74	12
0901-1100	132	20
1101-1300	157	15
1301-1500	102	6
1501-1700	69	6
1701-1900	38	1
1901-2100	19	0
Forest Type		
Coniferous	24	3
Coniferous Dominated Mixed	49	1
Mixed	111	13
Deciduous Dominated Mixed	137	16
Deciduous	232	29
Forest Density		
Dense	162	43
Some openings	291	14
Many openings	81	3
Location*		
Lakeshore	96	4
Backshore	259	52
Over Lake	57	1
Road Edge	289	9
Cottage Description		
Cottaged	47	1
Near Cottaged	153	7
Uncottaged	340	55
Perching Site		
Coniferous tree	13	6
Deciduous tree	70	2
Dead tree or hydro pole	37	2
Hydro wire	73	1
Ground	4	1
Observed Behaviour		
Flying	336	18
Perching	211	15
Feeding	10	3
Calling	141	37
At Nest	53	21
Hunting	18	0
Prey Species		
Mammal	4	1
Frog	1	
Bird	1	
Snake	3	
Unknown	3	
Earthworm	1	
Number Seen		
1	499	50
2	59	9
3	10	5
4	8	
6	1	

*551 observations, some overlap.

would circle together, and gradually drift apart, apparently observing territorial boundaries. Two pairs of hawks often soared near each other, calling. Birds, apparently paired, frequently soared together. Often two hawks that were apparently not paired, soared together while calling, then one or both folded their wings and dropped into the forest. Single hawks did this also . At an open lakeshore that formed the boundary of three hawk territories, three pairs soared together into a group while calling. The smaller birds, possibly males, from two of these pairs, soared more closely together and swooped at each other.

Intraspecific interactions also occurreed near the ground. In one case, a hawk flew over one edge of the clearing, calling, while another hawk did the same over the opposite edge. in another observation, two Broad-winged Hawks called from the forest edge along a highway. Two others flew into the forest near them from across the highway and considerable calling ensued. Elsewhere one hawk pursued another for approximately 75 m over a highway before the pursued raptor flew into the forest. Most low level interactions took place at a break in the forest canopy. On one study lake with narrow irregular bays, the lakeshore appeared to function as a territorial boundary. A perching hawk that called from one edge of the lakeshore was answered by a hawk across the bay that called while flying. Two other hawks then called and flew over the forest further down the shore.

6.5 DISCUSSION

Broad-winged Hawks were the most commonly observed raptors in the study area, outnumbering Red-tailed Hawks approximately 18 to 1. As both are relatively conspicuous because of their perching and soaring habits, this figure probably reflects relative abundance. However, the secretive behaviour and preference for closed forest of the Red-shouldered Hawk reduces its visibility, so that it is likely more common than the ratio of Broad-winged to Red-shouldered Hawk observations would indicate (7.2:1).

The Red-tailed Hawk is typically an open-country nesting bird (Gates 1972; McInvaille and Keith 1974), although it is adapted to a wide range of habitat conditions (Beebe 1974). Its nesting habitat is quite different from that of the other two species (Titus and Mosher 1981). Most observations of this raptor were made at its perching sites along roadsides and in areas with open beaver meadows and swamps. Nesting has been noted in Algonquin Park, northeast of our study area (Ontario Nest Record Scheme). Our limited behavioural observations suggest that the Broad-winged Hawk reacts aggressively to the Red-tailed Hawk, as does the Red-shouldered Hawk (Campbell 1975). With large scale increases in clearing activities in central Ontario, more habitat may become available to the Red-tailed Hawk increasing the potential for aggressive interaction.

Both raptor species frequent deciduous, upland forests near riparian or lakeshore habitat. The Broad-winged Hawk was more commonly found in partially open forests like those along roadways; the latter was almost totally restricted to closed forests. There were no significant differences in general nesting macrohabitat, with the possible exception of elevation, within a 3.14 ha circle surrounding the nests. Inclusion of this variable in the discriminant function seems to be a result of sampling bias. Several Broad-winged Hawk nests and most Red-shouldered Hawk nests were located in one area of low elevation. With the removal of elevation from the DFA, macrohabitat conditions were similar for nests of both species. General habitat conditions included location on a slope near a natural clearing, close to a water source, and in a predominantly deciduous forest. This association with slope and water was not due to emphasis on field work conducted near lakeshores, as nests were also located and studied in backshore regions. Broad-winged Hawk nests in the mid-western and nests of both species in the eastern U.S. show similar relationships with water and clearings (Keran 1978; Titus and Mosher 1981). Discriminant function analysis of four woodland raptor nesting sites in Maryland showed that Broad-winged and Red-shouldered Hawk nest sites could not be differentiated along the first discriminant function (weighted to distance to water and nest height); but they were separated along the second discriminant function (weighted to basal area, dbh of nest tree, and distance to nearest opening, (Titus and Mosher 1981).

On a larger scale (314 ha), Red-shouldered Hawk nesting habitat contains forested habitat, marsh habitat, and edge (Bednarz and Dinsmore 1981). In Iowa, Red-shouldered Hawks also rely on wetland habitat (bottomland forests and small wetlands) (ibid).

More specific habitat selection was involved in the precise nest location. Red-shouldered Hawk nests were usually found in areas with a lower number of trees, ground cover, and conifer composition. Their nests were generally higher and nest height was important in the discriminant function. Red-shouldered Hawk habitat was thus typically mature, deciduous forest, while Broad-winged Hawk habitat was younger, deciduous-dominated mixed forest. In southern Ontario, the Red-shouldered Hawk nests in similar habitats to those found in this study (Campbell 1975), although elsewhere they nest primarily in riparian areas (Stewart 1949; Portnoy and Dodge 1979; Galli et al. 1976). Stewart (1949) suggested that the Broad-winged Hawk would not compete with the Red-shouldered because of the former's affinity for upland habitats. In this study, Red-shouldered Hawk habitat fell into two broad categories: lowland riparian and upland deciduous. The Red-shouldered Hawk nested in only three species of tree, principally beech and yellow birch. The three species used here were the most commonly used nest trees in southwestern Quebec (Morris et al. in press). Beech or other species of birch have been commonly used elsewhere as nest trees (Stewart 1949; Henney et al. 1973; Campbell 1975). The Broad-winged Hawk nested in a variety of trees, but predominantly white birch, yellow birch, and sugar maple. Early studies indicated that trees were used mainly in accordance with their abundance (Burns 1911).

The overlapping of the nesting habitats of these two species would most likely occur in the moist, riparian, mixed wood slopes. At one location, a nest in a yellow birch which was probably used by Broad-winged Hawks in 1978 (territorial behaviour, fledged young in area) was utilized by Red-shouldered Hawks the following year. The Red-shouldered Hawk appears to have the advantage in competition for nesting sites, because its nesting activity begins earlier in central Ontario and elsewhere (Burns 1911; Henny et al. 1973; Matray 1974; Portnoy and Dodge 1979). Ravens *(Corvus corax)* have a similar advantage over nesting buteos

(Craighead and Mindell 1981). Red-shouldered Hawk nests were generally higher than those of Broad-winged Hawk nests, unlike western Maryland where the situation was reversed (Titus and Mosher 1978).

Newton (1976) suggested that where nesting sites are abundant, interspecific competition may only result in the displacement of one species to another site in the home range with no effect on breeding density. This would not likely be the case with these raptors, because of the aggressive interactions observed. Their nests were never found close together, and occupied territories appeared to be almost mutually exclusive. Both the Red-shouldered and Broad-winged Hawks require continuous forest areas, although the latter also requires open areas for perching sites. The Red-shouldered Hawk needs a minimum forest area of 10 ha (Galli et al. 1976) and possibly as much as 2500 ha of generally forested habitat (Bednarz and Dinsmore 1981). It was rarely seen outside of dense forest cover, while the Broad-winged often was.

The DFA for perching and nesting sites of the Broad-winged Hawk verified that open areas are valuable. On a macrohabitat scale, nesting and perching sites were clearly differentiated on the basis of clearing size, clearing adjacency, and slope. These results, combined with the heavy use of dead trees, transmission line wires, and exposed deciduous branches illustrate that exposed areas are preferred perching sites. Broad-winged Hawks also perch on the edge of clearings in Minnesota and Wisconsin (Keran 1978). These sites could be useful for both hunting and territorial displays. The few Red-tailed Hawk perching sites observed were similar.

These results suggest that cottage development may not seriously disrupt Broad-winged Hawk breeding habitat. Where no cottage development had occurred, dead trees in open beaver meadows and along lakeshores were used as perching sites. Broad-winged Hawk territories appeared to be separated along borders of unforested land, whether roadways, clearings, or shorelines. The Broad-winged Hawk apparently defends distinct, non-overlapping territorial boundaries along linear openings in the forest canopy. It seems to defend exclusive home ranges as does the Red-shouldered Hawk (Craighead and Craighead 1956; Newton 1976). This "activity centre" includes a defended breeding, nesting and feeding territory (Keran 1978).

Most intraspecific interactions near the ground usually occurred around clearings. If open areas are necessary to divide territories, the presence of lawns, roads, and hydro lines that occur with cottage development may increase the potential number of Broad-winged Hawk nest sites. A study in Maryland, using random samples, produced a relatively large number of misclassifications, suggesting nesting sites are not limited (Titus and Mosher 1981).

Aside from major habitat alteration, the greatest effect of cottaging on the Broad-winged Hawk may be caused by human disturbance. This species is most conspicuous in late May, probably due to activity associated with nest establishment. As the first major influx of cottagers occurs at that time (Victoria Day weekend), nest disturbance or desertion could result. The site tenacity of most raptors is weakest at the time of territorial establishment which could make it one of the most critical periods for nest desertion (Fyfe and Olendoff 1976). Heavy recreational use in Wyoming has had significant negative impacts on nesting buteos (Craighead and Mindell 1981).

The Red-shouldered Hawk did not respond positively to cottage development, although it often nested close to clearings and, in some cases, roads. Proportionally more sightings of this raptor occurred in uncottaged areas. Cottage roads that encircle lakes 50 to 100 m from the shore could fracture and isolate potentially valuable riparian and lakeshore habitat. The importance of nesting sites near permanent or seasonally used water has been documented elsewhere (Wiley 1975). The nesting success rate of the Red-shouldered Hawk is directly proportional to the distance between adjacent sites (Henney et al. 1973). This suggests that, if available breeding habitat were lost to cottage development, the response would be a reduction in breeding population or reproductive rate.

A nesting population of this raptor had not been documented in the study area before (Peck 1979). We documented 9 nesting attempts of this species although it is considered to be declining in central Canada and elsewhere in its range (Brown 1971; Fyfe 1976). It appears to be widely distributed in the study area, as there are large areas of suitable habitat and Red-shouldered Hawks were observed in areas where nests were not located. Given its general population status and the fact that nest trees may be limiting factors in otherwise suitable habitats (Titus and Mosher 1981), the effects of cottaging on habitat quality must be carefully considered in the context of its overall status.

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7. PREDICTING AVIAN COMMUNITY RESPONSE TO LAKESHORE COTTAGE DEVELOPMENT

K. CLARK, D. EULER and E. ARMSTRONG

7.1 SUMMARY

Managing lake shorelines for human recreational development without losing significant wildlife values is an important concern in Ontario. In order to assist resource managers in deciding how cottage development can best be managed, breeding songbird species were studied in both developed and undeveloped lakeshore habitats of central Ontario. An Index (GDI) which measures the area disturbed in the ground vegetation layer was significantly correlated with a number of habitat variables important in describing avian habitat. In general, the GDI was negatively correlated with foliage cover and volume, which reflected the removal of vegetation as disturbance occurred. Avian species could be placed in one of three groups: the ovenbird *(Seiurus aurocapillus)*, an example of the group found primarily in undeveloped habitats; the eastern phoebe *(Sayornis phoebe)*, one of the group found in highly disturbed habitats; and the veery *(Catharus fuscescens)*, part of the group which was not significantly affected by development. These findings present a simple model of breeding bird response to disturbance which can be used to minimize the negative impact of cottage development.

7.2 INTRODUCTION

As human activity encroaches on undeveloped areas, there is concern for the plant and animal communities located there. Avian species, which breed in North America and migrate to Central and South America in winter, are often greatly affected. Not only are their breeding habitats being altered, but their wintering grounds are being converted to pasture and farmland (Terborgh 1974). The majority of birds that breed in forests of central Ontario are neotropical migrants (MacArthur 1957). In the last 50 years, hundreds of lakes in this area have become popular for recreational activity. Cottages have been built along many lakeshores with associated roads and transmission line corridors nearby. Robertson and Flood (1980) found an increase in diversity of the songbird community along portions of cottaged lakeshore in the Rideau Lakes, Ontario. Martin (1960) investigated changes in bird populations in relation to forest succession, in the Algonquin Park area. James and Warner (1982) and several others have demonstrated that bird species diversity depends on vegetation structure and species composition. While these studies are helpful they do not give resource managers a tool to predict how future cottage development may affect bird communities along lakeshores. Unlike successional sequences, building cottages tends to impose permanent change in the vegetation and associated environment. There is a need for resource managers to have some ability to predict how changes imposed by this development will affect wildlife present in the area.

Racey and Euler (1981) devised three indices of habitat disturbance intended to predict changes in plant and animal populations caused by cottage development. These indices measure changes in vegetation in three layers: ground, shrub, and tree. The purpose of this study was to test the usefulness of these indices as predictors of avian species composition in cottaged and uncottaged habitats of central Ontario and to suggest ways in which these results could facilitate planning and management decisions.

7.3 METHODS

The study area is located in the ecotone between the Boreal and the Eastern Deciduous forests of Ontario (Fig. 7.1). It is characterized by a mixture of coniferous and deciduous species. White pine *(Pinus strobus)*, balsam fir *(Albies*

Figure 7.1 The study area.

balsamea), and eastern hemlock *(Tsuga canadensis)* are common, particularly along north-facing shorelines. Sugar maple *(Acer saccharum)* and red maple *(A. rubrum)* are present along south-facing shorelines and in back-shore areas. White birch *(Betula papyrifera)*, white cedar *(Thuja occidentalis)*, beech *(Fagus grandifolia)* and yellow birch *(Betula lutea)* occur throughout the area.

Seventy-three study plots of 1 ha each were selected to represent a continuum of developed and undeveloped habitats along shorelines. The undisturbed end of the continuum had no cottages at all while the disturbed end had the highest observed cottage densities. Three times between the 26 May and 20 July of 1978 and 1979, singing males were counted, using the spot map method (Williams 1939; Kendeigh 1944). All singing males were mapped on 10-m by 10-m grids within the plot during a four hour period beginning no later than 0700 h. A species was considered breeding if a singing male was encountered on two or three visits or was encountered at least five times on one visit.

Eighteen habitat variables (Table 7.1) which are important in describing avian community composition (James 1971; Whitmore 1975, 1977; Smith 1977) were measured on a T-shaped area centered on the plot. The T-shape consisted of two quadrats 20 m deep and 50 m long. One was parallel and adjacent to the lakeshore; the other was prependicular to the first quadrat, thereby forming a T-shape. Foliage volume and cover were measured on 50 randomly selected 1-m^2 quadrats within the "T". The percent of vegetation in each layer (ground 0-1 m, shrub 1-9 m, and tree >9 m) was estimated for each quadrat for a column extending to the top of the canopy. All trees (dbh>8 cm), shrubs (dbh <8 cm), and snags were counted within the "T".

For each plot, three development indices were computed to measure disturbance in the ground (GDI – Ground Disturbance Index), shrub (SDI – Shrub Disturbance Index), and tree layers (TDI – Tree Disturbance Index). The disturbed area on each plot was measured for each layer. Any area which had been altered by human activity, where a man-made structure existed, or where natural succession had been arrested, was classified as disturbed. The area disturbed in a layer (in hectares) divided by the total plot area (1 ha) was equal to the development index for that layer.

The coniferous composition of each plot was determined by mapping the area where 50% or more of the canopy foliage was coniferous. That area multiplied by 100 gave the percent conifer composition for that plot. In highly disturbed habitats where the canopy had been removed, the coniferous composition was estimated by examining surrounding ground, shrub, and tree species for indication of previous composition. Plots were coniferous if the percent conifer composition was 51% or more; deciduous if the percent conifer composition was 50% or less. These were analysed separately to examine their different habitat structures and avian communities (MacArthur 1957).

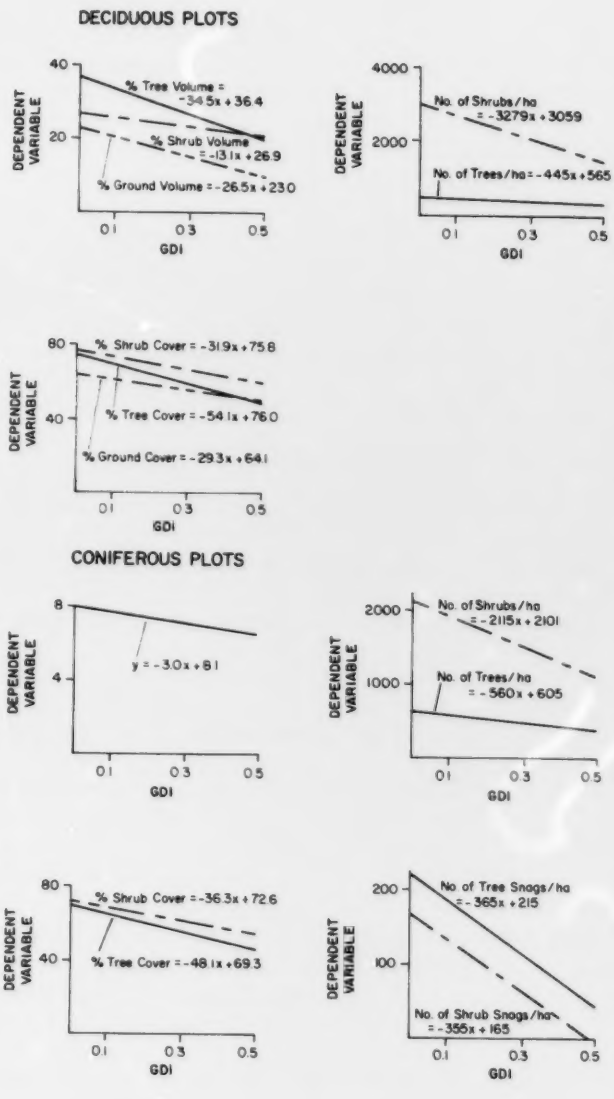

DECIDUOUS PLOTS
DEPENDENT VARIABLE
% Tree Volume = -34.5x + 36.4
% Shrub Volume = -13.1x + 26.9
% Ground Volume = -26.5x + 23.0
No. of Shrubs/ha = -3279x + 3059
No. of Trees/ha = -445x + 565
% Shrub Cover = -31.9x + 75.8
% Tree Cover = -54.1x + 76.0
% Ground Cover = -29.3x + 64.1
CONIFEROUS PLOTS
y = -3.0x + 8.1
No. of Shrubs/ha = -2115x + 2101
No. of Trees/ha = -560x + 605
% Shrub Cover = -36.3x + 72.6
% Tree Cover = -48.1x + 69.3
No. of Tree Snags/ha = -365x + 215
No. of Shrub Snags/ha = -355x + 165
GDI

Figure 7.2 Linear regressions between habitat characteristics and the Ground Development Index (GDI) for deciduous and coniferous plots.

Table 7.1 Correlation Coefficients for the association between disturbances in the Ground (GDI), Shrub (SDI), and Tree (TDI) layers and habitat variables.

Habitat Variables	Deciduous (N = 32)			Coniferous (N = 41)		
	GDI	SDI	TDI	GDI	SDI	TDI
Ground Volume	-.667*	-.631*	-.611*	-.295	-.045	-.239
Shrub Volume	-.370*	-.369*	-.334*	-.095	-.175	-.115
Tree Volume	-.574*	-.535*	-.455*	-.243	-.211	-.292
Ground Coverage	-.391*	-.353*	-.389*	-.050	-.129	-.043
Shrub Coverage	-.502*	-.491*	-.479*	-.489*	-.227	-.491*
Tree Coverage	-.570*	-.509*	-.458*	-.510*	-.275	-.527*
No. Ground Species	.376*	.312	.278	.012	-.010	.189
No. Shrub Species	.049	.099	.042	-.003	.212	.011
No. Tree Species	-.168	-.174	-.130	-.339*	-.109	-.331*
No. Ground Individuals	.112	.088	.072	-.071	-.202	-.023
No. Shrub Individuals	-.604*	-.551*	-.581*	-.408*	-.172	-.350*
No. Tree Individuals	-.456*	-.398*	-.450*	-.491*	-.338*	-.475*
Foliage Height Diversity**	-.482	-.450*	-.466*	-.349*	-.168	-.395*
No. Tree Snags	-.274	-.273	-.254	-.305*	-.200	-.271
No. Shrub Snags	-.201	-.176	-.184	-.3217*	-.069	-.319*

*$p<0.05$ correlation table.

**As measured by MacArthur and MacArthur (1961).

Table 7.2 Number of deciduous plots on which a species was present for two sets of intervals (I and II) of the Ground Development Index (GDI)

Species	I			II	
	No. of Plots Where				
	GDI≤.10	GDI>.10	GDI=0	0<GDI≤.35	GDI>.35
	n 21	11	20	6	6
Northern Waterthrush *(Seiurus noveboracensis)*	5*	1*	5*	0*	1
Red-eyed Vireo	20**	10**	19**	6**	5
American Redstart *(Setophaga ruticilla)*	12	4	11	3	3
Least Flycatcher *(Empidonax minimus)*	11	3	10	2	2
Ovenbird	11	3	11	2	1
Rose-breasted Grosbeak *(Pheucticus ludovicianus)*	9	4	8	2	3
Chestnut-sided Warbler *(Dendroica pennsylvanica)*	7	3	6	1	3
Black-throated Blue Warbler *(Dendroica caerulescens)*	8	1*	8	1	0*
Veery	14	9	13	5	5
Blackburnian Warbler *(Dendroica fusca)*	6	4	6	3	1
Black-throated Green Warbler	5*	1*	5*	1	0**
Yellow Bellied Sapsucker *(Sphyrapicus varius)*	2*	4	4*	2	0**
Black and White Warbler *(Mniotilta varia)*	5*	2	5*	2	0**
Yellow Warbler *(Dendroica petechia)*	4*	4	3*	4	1
Song Sparrow *(Melospiza melodia)*	2*	7	2	4	3
American Robin	0*	7	0*	2	5
Phoebe	1*	3	1*	1	2
Brown-headed Cowbird	5*	2	1*	1	5
Dark-eyed Junco	2*	3	2*	2	1
White-throated Sparrow *(Zonothrichia albicollis)*	1*	4	1*	1	3
Chipping Sparrow *(Spizella passerina)*	0*	5	0*	3	2
Black-capped Chickadee *(Parus atricapillus)*	0*	6	3*	0*	3
Eastern Wood Pewee *(Contopus virens)*	3*	2	0*	0*	5

*Sign test $p \leq 0.05$ that a species would be absent more frequently than expected by chance alone at that interval of GDI.

**Sign test $p \leq 0.05$ that a species would be present more frequently than expected by chance alone at that interval of GDI.

7.4 RESULTS

Although the addition of man-made features like buildings and roads can affect avian communities, a measurement of vegetation alteration is adequate to predict changes in those communities (Lancaster and Rees 1979). The significant correlations of the GDI, SDI, and TDI with the measured habitat variables indicate that each of these indices was a useful tool to measure alterations in avian habitat (Table 7.1). All significant associations except the number of ground species responded negatively to development.

The positive association of the number of ground species with development in deciduous habitats can be attributed to the creation of lawns and mowed fields around cottages. These habitats are composed of many early successional annuals and perennials. In coniferous habitats, however, few annuals and perennials can tolerate the acidic soil created by coniferous vegetation. Since mature, coniferous forests have little ground cover, cottage development in these areas does not reduce this cover much.

In coniferous habitats, the number of tree species was negatively associated with the GDI and the TDI, because many cottagers had removed hemlock and balsam from their lots. On deciduous lots, cottagers did not show a strong preference for any particular tree species, which accounted for the insignificant association of the number of species with the GDI.

Regression analysis was used to express relationships between habitat characteristics and the GDI. Regression lines were fitted (Fig. 7.2) according to linear analysis using BMD-PIR programs (Dixon 1975).

Relationships between avian species and the GDI could not be determined using regression analysis as more than one breeding pair of a species was seldom found on one plot. Instead, a sign test was used to determine whether a species was present on a plot more often than once at different levels of the GDI (low = 0; high < 0.10) (Tables 7.2, 7.3). To obtain a more detailed test of the occurrence of each species with development, the sign test was repeated using different intervals of development: low (GDI = 0), intermediate ($0 < GDI < 0.35$ for deciduous plots; $0 < GDI < 0.20$ for

Table 7.3 Number of coniferous plots on which a species was present for two sets (I and II) of the Ground Development Index (GDI).

Species	I			II	
	No. of Plots Where				
	GDI≤.10	GDI>.10	GDI=0	0<GDI≤.35	GDI>.35
	n 19	22	13	17	11
Ovenbird	16**	9	12**	9	4
Canada Warbler	4*	2*	3	2*	1*
Solitary Vireo	6	2*	4	3*	1*
Winter Wren *(Troglodytes troglodytes)*	7	2*	0	8*	1*
Black-throated Green Warbler *(Dendroica virens)*	6	2*	5	3*	0*
Swainson's Thrush *(Hylocichla ustulata)*	6	1*	5	2*	0*
Black-throated Blue Warbler	6	3*	5	4*	0*
Northern Waterthrush	9	2*	7	4*	0*
Blackburnian Warbler	16**	10	10	11	5
Rose-breasted Grosbeak	3*	8	3	6	2
Yellow Warbler	12	16	9	11	8
Black and White Warbler	11	7	9	5	4
Veery	5	9	5	5	4
White-throated Sparrow	7	4*	5	4*	2
Red-eyed Vireo	8	19**	3	15**	9
American Robin	0*	15	0*	7	8**
Brown-headed Cowbird	1*	8	0*	6	3
American Redstart	0*	5	2	0*	7
Phoebe	0*	7	0*	3*	4
Chestnut-sided Warbler	1*	7	0*	4*	4
Song Sparrow	3*	7	1*	4*	5
Least Flycatcher	0*	6	0*	4*	2
Yellow-bellied Sapsucker	2*	5*	2*	3*	2
Dark-eyed Junco *(Junco hyemalis)*	3*	5*	2*	3*	3
Cedar Waxwing *(Bombycilla cedrorum)*	0*	0*	2	0*	2*
Chipping Sparrow	2*	3*	0*	4*	1*

*Sign test $p \leq 0.05$ that a species would be absent more frequently than expected by chance alone at that interval of GDI.

**Sign test $p \leq 0.05$ that a species would be present more frequently than expected by chance alone at that interval of GDI.

coniferous plots), and high (GDI > 0.35 for deciduous plots; GDI > 0.20 for coniferous plots). The results illustrate the probability of finding a breeding pair of each species at each level of development (Fig. 7.3, 7.4).

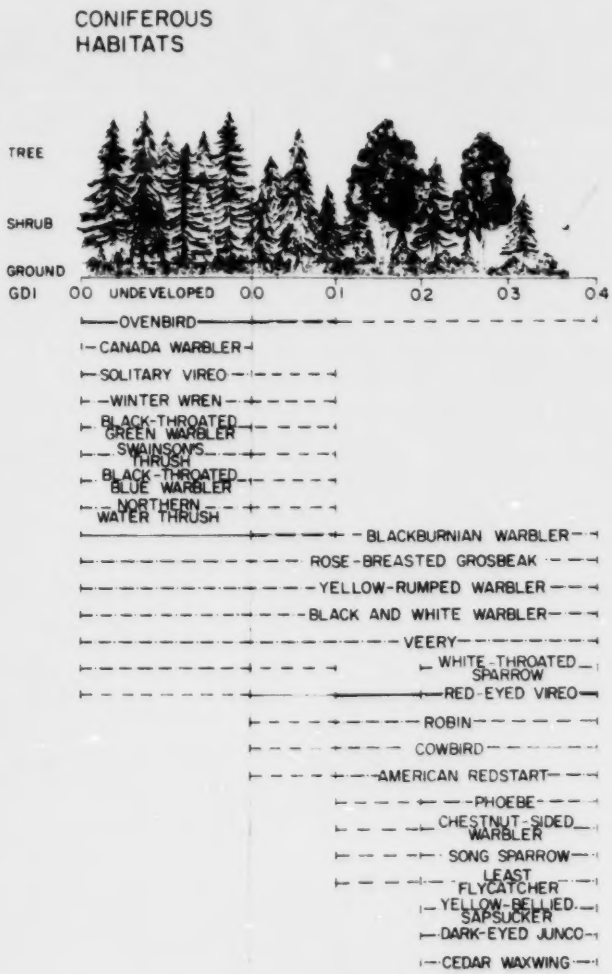
A definite change in community composition occurred as development increased (Tables 7.2, 7.3). The ovenbird, Canada warbler, solitary vireo, winter wren, and black-throated green warbler, for example, were associated with mature forest, and were intolerant of habitat disturbance (MacClintock et al. 1977; Whitcomb et al. 1977; Conner and Adkisson 1975). The species found at high levels of development in this study included the robin, phoebe, cowbird, and dark-eyed junco. These species were found in open habitats created by cottage development similar to the habitat type where they are found in other parts of their range (Howell 1942; Young 1955; Hespenheide 1971; Robertson and Flood 1980). A third group of birds, relatively indifferent to development, included the rose-breasted grosbeak, red-eyed vireo, and veery. These species are often associated with immature forest habitat (Webb et al. 1977; Possardt and Dodge 1978), and were found in undeveloped habitats where deadfalls had created openings in the canopy. These birds could also be found at the edges of cottage clearings and in cleared areas which have been allowed to revert to secondary succession with many shrubs and small trees.

To measure the amount of change in species composition that is caused by cottage development, the Coefficient of Community was computed for each plot (Jaccard 1932).

$$CC_i = (c/a + b_i - c) \times 100 \qquad (1)$$

where CC = coefficient of community
a = number of avian species on the most highly developed plot
b_i = number of avian species on the plot
c = number of avian species common to both plots
i = plot for which CC is being calculated

Coefficient of Community measures the degree to which the species composition resembles that of the most highly disturbed plot.



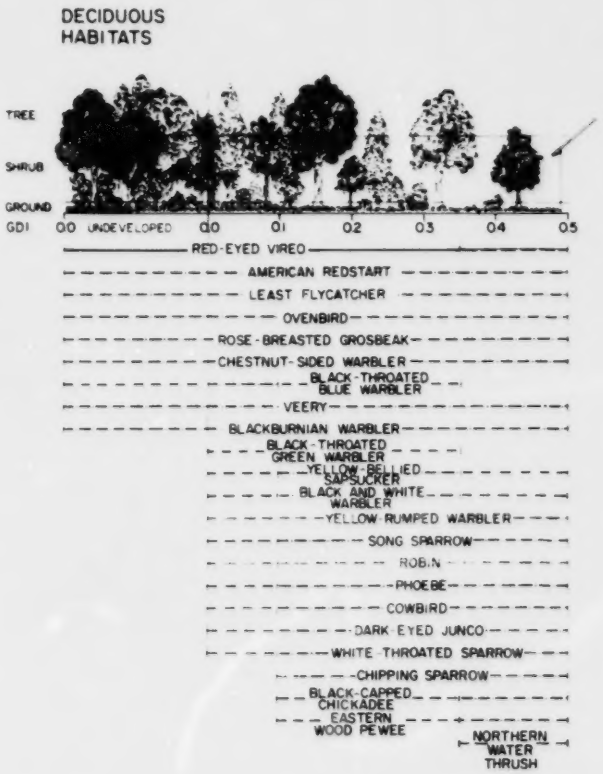


Figure 7.3 Occurrence of bird species at varying levels of development (GDI) in coniferous habitats. The density of each line represents the probability of each species being present at that level of development (indicated by the results of 2 sets of sign tests).
——— Both sign tests positive.
——— One sign test positive, second non-significant
—·—·—·— Both sign tests non-significant.
– – – – – One sign test non-significant, second negative. Both sign tests negative.

Figure 7.4 Likelihood of occurrence of bird species at varying levels of development (GDI) in deciduous habitats. Intensity of each line represents the likelihood of a species occurring at taht level of development (indicated by the results of 2 sets of sign tests).
——— Both sign tests positive.
——— One sign test positive, second non-significant
—·—·—·— Both sign tests non-significant.
– – – – – One sign test non-significant, second negative. Both sign tests negative.

To examine coniferous habitats, all plots were measured against a plot with a GDI of 0.87; for deciduous habitats, a plot with a GDI of 0.51. Small values of CC indicated a species composition different from that of a developed habitat; large values indicated a species composition similar to that found on the most highly developed plot. A linear regression analysis was used to express the relationship between CC and the GDI (Fig. 7.5). The regression line had a positive slope, with a small value of CC on undeveloped plots (GDI = 0, coniferous plots CC = 15; deciduous plots CC = 34). The change in CC with development could occur if species were added with development and none lost. The change in CC could also be attributed to the loss of species found only in undeveloped habitats which were replaced by species associated with disturbed habitats. To determine if the number of a species was increasing with development, a linear regression was computed between the number of breeding bird species and the GDI. The regression was significant only in deciduous habitats (Fig. 7.6) ($p<0.05$, $r = 0.78$). For deciduous plots, the slope of the line was 3.1 which indicated that the change in the level of the GDI from 0 to 0.51 resulted in the addition of 1.58 (3.1 x 0.51) species. The absence of these 1.58 species on undeveloped plots would have changed with the CC by 18% (1.58/8.6 x 100) where 8.6 was the number of species present (GDI = 0.510). The CC of deciduous plots increased by 66% between the GDI values of 0 and 0.51. Of this increase, 18% was attributed to the addition of species in developed habitats and 50% to the replacement of species in undisturbed habitats by species tolerant of development. Because species number did not change with the GDI in coniferous habitats, a change of 85% in the CC in undisturbed habitats was attributed to the replacement of tolerant species as development increased.

7.5 DISCUSSION

The purpose of this work was not to measure songbird populations and their response to cottage development. Songbird populations are notoriously difficult to measure and the populations themselves fluctuate widely. Preston (1960) noted that for 57 breeding species in Ohio based on 10 years of survey data, only about half (28 species) bred every year. James and Warner (1982) showed that study plots of less than 10 ha often have less than the total birds breeding in an area. In this work, based on two years of data and small sample plots, we cannot hope to show the long-term comprehensive impact of cottage construction on songbird populations. The need, however, is for a relatively simple model of cottage development and the resulting impact on the wildlife community. A model which illustrates the basic change imposed by development will be useful because it will give planners the background from which to make rational decisions. As these decisions are made and their "corrections" tested, the ability to make better decisions should be increased. The goal is not perfection, rather a realistic assessment of how human activity changes the natured world.

Under these circumstances the best predictor of changes in avian habitat alteration was the GDI. It had the highest correlation coefficients with the habitat variables and of the indices, was less susceptible to observer bias. The level of disturbance was usually clear and obvious; it was either completely changed by a lawn or a building or it was not disturbed at all.

Knowing the relationships between the GDI and avian community composition, predictions can be made regarding the effects of proposed cottage developments. Racey and Euler (1981) found that a mean of 0.13 ha of the ground layer was disturbed in every cottage clearing and that the area disturbed

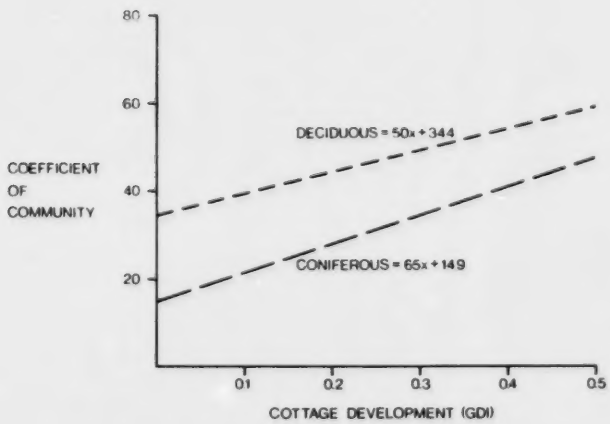


Figure 7.5 Linear regressions between the Coefficient of Community and the Ground Disturbance Index in deciduous and coniferous plots.

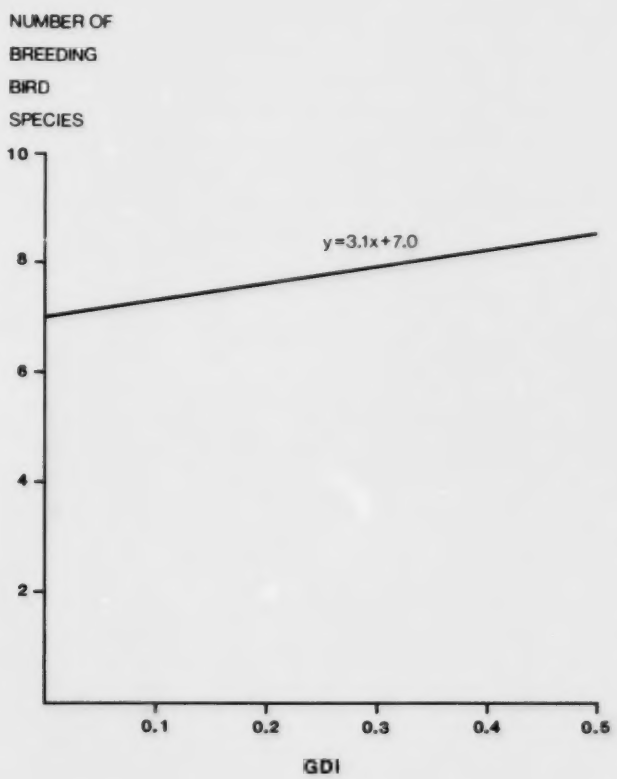


Figure 7.6 Linear regressions between the number of breeding bird species and GDI in deciduous plots.

was not dependent on lot size. The disturbed area was usually 20 m from the shore. It included clearings for the access road, hydro lines, and buildings. If the placement of cottages along a lakeshore is known, the value of the GDI can then be calculated for each 100 m of shoreline (Fig. 7.7). Predictions can then be made about the amount of change that will occur in avian species composition as a result of the habitat disturbance.

Using development plans on which the proposed placement of cottages, roads, and transmission line corridors is mapped, the GDI could be computed for each 100 m of shoreline, starting from a random point along the shore. Impact of the development on avian species composition could then be assessed. Tolerable levels of change could be defined and practices determined to minimize the intolerable disturbances.

Some species like the ovenbird, Canada warbler, and solitary vireo cannot tolerate any level of development. If these species are to breed along a lakeshore, some areas of it would have to be left totally undisturbed. Other birds, found only in undisturbed habitats, are so widely dispersed that large sections of habitat must be set aside to maintain even small populations.

Species most likely to utilize disturbed areas are associated with grassland and edge habitats. Grassland species tend to be more adaptable than forest birds (Anderson 1979). Greater consideration should, therefore, be given to the less flexible forest species in any assessment of the effects of habitat disturbance on the avian community.

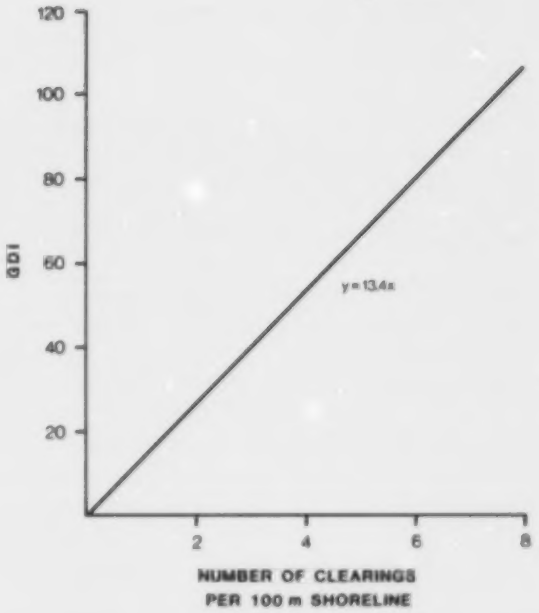


Figure 7.7 The relationship between GDI and the number of cottage clearings/ha.

7.6 ACKNOWLEDGEMENTS

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8. CHANGES IN MINK HABITAT AND FOOD SELECTION AS INFLUENCED BY COTTAGE DEVELOPMENT IN CENTRAL ONTARIO

G. RACEY and D. EULER

8.1 SUMMARY

Shoreline cottage development in central Ontario affected mink habitat and food selection by altering vegetation structure and distribution, species composition of vegetation, and prey availability. Lot clearing activities by cottagers reduced tree and shrub densities, foliage volumes, deadfalls and shade-loving ground species while increasing the number of alien or domesticated plant species. The littoral zone was simplified by the removal of submerged snags, large boulders or stones, subemergent, emergent, and floating vegetation in favour of sand beaches and docks. Mink activity decreased with increasing levels of development, as measured by a development index, and increased with increasing coniferous composition. Deciduous shorelines were not used much by mink regardless of the level of development. The occurrence of fish, amphibians and crustaceans in the diet was affected by the intensity of development while the occurrence of mammals, crustaceans and amphibians in the diet was affected by the coniferous composition of the habitat. It is important to understand these changes in order to manage the development to minimize negative impacts on wildlife.

8.2 INTRODUCTION

Mink (*Mustela vison*) are economically important furbearers throughout most of North America. They are also top level predators occupying a niche that incorporates both aquatic and terrestrial ecosystems into their food web. These characteristics make mink an excellent source of information regarding the effect of perturbations on shoreline habitats.

Cottage development and the associated lot clearing and road building activity directly affects shoreline vegetation along lakeshores. All wildlife present along the shoreline may be affected directly or indirectly by this alteration to the vegetation structure and human presence. Mink are a useful example to study feeding behaviour and habitat selection in both prey populations and vegetation which result from the cottage development process. Several studies of mink have involved the identification of animal remains contained in the stomach and intestines of mink carcasses obtained during trapping seasons (Hamilton 1959). In summer, mink studies have often concentrated on the analysis of mink scats collected in wetland areas and along streams (Dearborn 1932; Hamilton 1940, 1959). Mink movements and territorial behaviour have also been studied in North America (Mitchell 1969) and in Sweden (Gerell 1967, 1970) where mink have been introduced in the past 60 years. Little is known, however, of the ways in which vegetation alternation affects mink habitat selection and feeding behaviour.

The purpose of this paper is to investigate the effects of cottage development upon mink activity, feeding patterns and habitat selection in the spring and where possible to relate behavioural changes in alterations in shoreline habitat.

8.3 METHODS

8.3.1 STUDY AREA

Shorelines of 26 lakes were searched for signs of mink activity over a six week period in May and June of 1978 and 1979. Seven of these, less than 90 ha in size, were used in their entirety along with sections of the other 19 lakes to provide a total of 72,500 m of shoreline. The lakeshores were selected to represent a wide range of vegetation and development characteristics typical of the Muskoka-Haliburton region. All of the lakes studied are located within a 50 km radius of Dorset (Fig. 8.1).

Figure 8.1 Map of the study area in central Ontario.

Archaean and Proterozoic igneous rock formations of the Canadian Shield are the predominant physiographic features. Conifers along shorelines include white cedar *(Thuja occidentalis)*, eastern hemlock *(Tsuga canadensis)*, balsam fir *(Abies balsamea)* and white pine *(Pinus strobus)*, while deciduous shorelines are made up of white birch *(Betula papyrifera)*, largetooth aspen *(Populus grandidentata)*, sugar maple *(Acer saccharum)*, red maple *(Acer rubrum)*, red oak *(Quercus rubra)*, American beech *(Fagus grandifolia)* and yellow birch *(Betula alleghaniensis)*. A coniferous fringe is present to some extent on almost all shorelines and is most pronounced on north and east-facing shores. Virtually all land surrounding lakes is private, in whole or in part, and many lakes have no public access. All but the smallest lakes in the study area exhibit cottage or commercial development to some degree. Each area examined was suitable for cottage development; extensive wetlands, rivers and unusually steep rocky slopes were not studied.

8.3.2 VEGETATION ANALYSIS

Major components of the shoreline habitat were sampled on 94 plots, 50 x 20 m, classified by level of development (low, medium, and high), vegetative composition (coniferous, mixed, and deciduous) and level of observed mink activity. Each plot was bisected by the shore/water interface, creating two 50 x 10-m plots, parallel to the shoreline, on which aquatic and terrestrial habitats were sampled. Terrestrial vegetation was sampled on three 100-m^2 subplots while the entire aquatic portion of the plot was sampled. On each subplot, trees (> 10 cm dbh) and shrubs (< 10 cm dbh) were counted. Ground vegetation and seedlings were counted in two 1-m^2 randomly selected quadrats in each of the three subplots.

In addition, 17 structural parameters were measured on each subplot (Table 8.1) and 13 variables were measured in the aquatic portion of the plot (Table 8.2). The redundant or irrelevant variables were discarded using multivariate techniques described by Beale et al. (1967) and Jolliffe (1972). Principal component analysis was used to identify the major axes of variability in the vegetation.

8.3.3 DENS

Seventeen physical and vegetative variables were measured in a 9.0 m diameter circle centred on the den (Table 8.3). A foliage board (2.0 m x 0.33 m) divided into six equal segments was used to estimate horizontal cover. The sum of the percent of each segment obscured by vegetation gave a maximum value of 600. Four ground shrub, tree coverage values and foliage board score values were estimated at 1.0 and 3.5 m from the den on two transects intersecting on the entrance to the den and oriented parallel and perpendicular to the shoreline. Vegetation coverage was estimated by the presence or absence of ground (< 1.5 m), shrub (1.5 - 9.0 m) and tree (> 9.0 m) vegetation on the four corners of a 1.0 m^2 column projected to the top of the canopy. The orientation of the den entrance to the lake was measured with a compass and the SINE and COSINE of the aspect was calculated to quantify the east-west and north-south orientation respectively.

Table 8.1 Definition of 17 structural variables measured on the vegetation subplots.

Variable	Definition
Ground Coverage	Sum of presence-absence measures of ground vegetation (< 1.5 m) on the 4 corners of the 1-m^2 quadrats
Shrub Coverage	Sum of presence-absence measures of shrub vegetation (1.5 m < shrubs < 9 m) on the 4 corners of the 1-m^2 quadrats
Tree Coverage	Sum of presence-absence measures of shrub vegetation (> 9 m) on the 4 corners of the 1-m^2 quadrats
Ground Volume	Estimate of percent of a 1-m^2 column, 1.5m high, which was taken up by ground vegetation in each quadrat
Shrub Volume	Estimate of the percent of 1-m^2 column between 1.5 and 9 m taken up by shrub vegetation on quadrats
Tree Volume	Estimate of percent of 1-m^2 column greater than 9 m and less than the canopy height taken up by tree vegetation on quadrats
Foliage Height Diversity	FHD calculated from ground, shrub and tree coverage values using Shannon's information statistic $H^1 = \sum_{i=1}^{n} p_i \log P_i$
Vegetation Volume	Sum of ground, shrub and tree volumes
Volume Diversity	Product of foliage height diversity and percent vegetation volume
No. of Shrub Groups	Thirty-two shrub groups (containing closely related species) were represented in the data
Shrub Species Diversity	Diversity of Shrub functional groups by Shannon's index
Conifer composition	Total number of coniferous shrubs divided by the total number of shrubs
Total No. of shrubs	Total number of shrubs individuals
No. of tree species	Seventeen tree groups (containing closely related species) represented in the data
Tree Species Diversity	Diversity of tree functional groups by Shannon's index
Percent Conifer Composition Trees (%)	Total number of coniferous trees divided by the total number of trees multiplied by 100
Total No. of trees	Total number of tree individuals counted

8.3.4 SHOREWALKING

The entire length of shoreline, within 5 m of the water, was searched for mink scats which were usually quite conspicuous. Gerell (1967, 1968) noted that scats are often found on prominent terrain features like rocks, stumps, grassy hummocks as well as near the entrance of dens. Most shorelines were walked three times over a six week period in May and June of 1978 and twice in the same period in 1979 to coincide with the maternal denning season of mink. The shorelines were searched for scats, scent posts and dens. Scats were collected individually in paper envelopes which were numbered and labelled according to a qualitative assessment

of the site's coniferous composition and development: habitat was classified as being deciduous, coniferous or mixed. Development was ranked on a scale of 1.0 to 3.0 with low values assigned to areas with no habitat disturbance within 30 m of the scat and/or cottages well spread out along that section of shoreline, and high values depicting areas of extensive vegetation clearing near the scat location and dense cottage development. Scent posts were considered as locations where one or more scats were found on more than one circuit of the shore. Dens were located by noting accumulations of scats near holes of at least 10 cm in diameter (Schladweiler and Storm 1969). Dens were marked with flagging tape and the locations of scats, scent posts, tracks and dens were recorded on chronoflex enlargements of aerial photographs of the lakes (scale 1:5000). Scats around dens were not collected until the final shore walk to minimize possible disturbance to resident mink.

Scats were air-dried and examined under a stereoscope. Scat contents were classified according to one of nine component groups representing basic feeding regimes: mammals, birds, fish, amphibians, reptiles, insects, crustaceans, plants or other. The presence or absence of each group was noted for each scat. This frequency of occurrence method was utilized by Hamilton (1959) on the stomach contents of mink and by Gerell (1967, 1968) on mink scats.

Chi square tests of independence were used to evaluate the dependence of mink activity and food selection on both habitat type and intensity of shoreline development. The expected number of scats found in each habitat type was calculated as the product of the proportion of shoreline studied that belonged to that habitat type and the total number of scats observed.

Table 8.2 Definitions of the 13 variables measured on the 10 x 50 aquatic portion of the 94 study plots.

Variable	Definition
Rock	% of shoreline of plot composed of bare rock
Snags	Number of snags > 10 cm dia. partially or completely submerged
Slope	Average slope of shoreline in degrees
Emergent	% of shoreline of plot fronted by emergent vegetation
Floating	% of shoreline of plot fronted by floating vegetation
Submerged	% of shoreline of plot fronted by submergent vegetation
Shrubs	% of shoreline of plot fronted by overhanging shrub vegetation
Trees	% of shoreline of plot fronted by overhanging tree vegetation
Bare	% of shoreline of plot with bare soil or sand
Depth 1	Depth of water 1 m from the shore
Depth 5	Depth of water 5 m from the shore
Homo	Substrate homogeneity of littoral zone ranked from 1 (very even) to 5 (highly diverse)
Size	Substrate size; a value of 1 to 5 based on size of the most common substrate particle.

Table 8.3 Definitions and the univariate statistics of the 17[a] variables measured in the 9 m diameter circle centred on each of the 59 mink dens found.

Variable	Definition	Mean	Standard Deviation
PCC	Percent conifer composition	76.152 ±	25.978
PCROCK	Percent rock	21.695 ±	26.471
SLA	Average slope	28.881 ±	17.274
GCI	Ground coverage at 1m from den	8.678 ±	3.688
SCI	Shrub coverage at 1m from den	13.983 ±	3.319
TCI	Tree coverage at 1m from den	10.797 ±	5.561
FBI	Foliage board measures 1m from den	121.203 ±	121.009
GC3.5	Ground coverage at 3.5m from den	8.085 ±	3.525
SC3.5	Shrub coverage at 3.5m from den	12.288 ±	3.306
TC3.5	Tree coverage at 3.5m from den	9.492 ±	5.444
FB3.5	Foliage board measures at 3.5m from den	188.673 ±	137.435
HTC	Height above den of 1st conifer branch	1.354 ±	0.988
HTD	Height above den of 1st deciduous branch	1.802 ±	1.691
NST	Number of stumps and hummocks	7.847 ±	4.378
NDED	Number of deadfalls 10 cm dia.	1.593 ±	1.555
COSASP	COSINE of the aspect of the den	0.136 ±	0.702
SINASP	SINE of the aspect of the den	0.126 ±	0.700

8.3.5 INDICES

The quantification of otherwise subjective criteria such as mink activity and development was achieved through the creation of indices. A mink activity factor (M) was calculated for 50 m to each side of each plot by the following equation:

$$M = S + P + D + T \quad (1)$$

where: S = log (number of scats)
P = 1 for minor scent posts,
2 for major scent posts
D = 2 for a possible den,
5 for a confirmed den
T = 1 if the only sign of mink activity was tracks.

A possible den lacked fresh scats nearby on at least one of the shorewalking rounds while a confirmed den had fresh signs of mink activity on each round.

The degree of habitat alteration caused by development was measured with a Development Index (DI) calculated by the following formula:

$$DI = (Ag + As + At)/Area \quad (2)$$

where: Ag = area disturbed in the ground layer
As = area disturbed in the shrub layer
At = area disturbed in the tree layer
Area = total area of terrestrial portion of plot (500 m^2).

The DI has a value of 3.0 when all vegetation on the plot is entirely disturbed by cottage development. A section of a vegetation layer was considered disturbed if a building or other man-made object occupied it. An area was also considered disturbed if human activities had altered natural succession by returning an area to, or maintaining the area at, an earlier successional stage.

A Development Index was also calculated for the entire lake. The Cottage Loading Development Index (CLDI), illustrated in Equation 3, quantifies the intensity and distribution of cottage development on a lake in relation to the size of that lake.

$$CLDI = \log (C \cdot D)/(U \cdot A) \qquad (3)$$

where: C = the number of cottages on the lake
D = the length of shoreline developed (m)
U = the length of shoreline undeveloped (m)
A = the surface area of the lake (ha)

The length of shoreline undeveloped was used instead of total shoreline to emphasize differences at extremely high or extremely low levels of development.

8.4 RESULTS AND DISCUSSION

8.4.1 VEGETATION ANALYSIS

The vegetation data were simplified by rejecting redundant and irrelevant variables. This was based on the assumption that any explicable relationship between habitat and mink activity would be found using the variables that define the major sources of variability between the plots. The first two principal components, explaining 16.0% of the total variance of shoreline ecotone sample, described axes of development and coniferous composition respectively. The first principal component described the extent of habitat disturbance with the Development Index (DI). Plant species of the pea (Fabaceae) and grass (Gramineae) families were on the negative end while foliage volumes, tree and shrub densities, mosses (Bryophyta) and emergent and submergent aquatic vegetation defined the antipode. The second principal component described an axis based upon coniferous composition of the habitat. The variables describing the deciduous end of this component included the trees, sugar and red maple, the shrubs, sweet gale *(Myrica gale)* and bog rosemary *(Andromeda glaucophylla)* and number of species of emergent vegetation. The coniferous end of the second component was described by the percentage of coniferous composition in the tree and shrub layers.

The Development Index is a direct measure of the amount of vegetation clearing. A significant negative correlation ($P < 0.001$) was found between the DI and the number of trees, foliage volume measures and foliage height distribution.

Although the total number of trees on the plot showed a significant decrease with development, this change was noted primarily in the three tree species that produced the coniferous fringe on both deciduous and coniferous plots: balsam fir, eastern hemlock and white cedar. The coniferous fringe is very important in determining the actual species composition of the plant community within 10 m of the shorelines.

Table 8.4 Observed and expected number of scats found in each of the coniferous composition and development categories. The expected values were calculated from the total number of scats found in proportion to the length of shoreline studied in each of the development and coniferous composition categories. The hypothesis of independence was rejected ($p < 0.001$).

	Coniferous Composition			
Development	Deciduous	Mixed	Coniferous	Totals
Observed number of Scats				
Low Development	60	482	576	1118
Medium Development	5	68	59	132
High Development	17	47	7	71
Total Observed	82	597	642	1321
Expected Values				
Low Development	141.3	287.7	281.3	705.3
Medium Development	110.9	163.8	33.0	307.7
High Development	71.3	109.6	122.8	303.7
Total Expected	323.5	556.1	437.1	1316.7

Table 8.5 Results of mink food habits analysis compared to that of Hamilton (1959).

	Current Study	Hamilton (1959)
Season	Spring	Summer
Number of Scats	1321	561
Study Area	Lakeshores in central Ontario	Rivers and marshes in New York State
Food Items		
Mammals	49.0	44.0
Birds	1.8	9.3
Fish	34.5	32.4
Amphibians	25.0	18.9
Crustaceans	23.9	12.7
Insects	14.5	29.2
Plants	2.0	
Reptiles	ND	4.1
Unidentified	8.3	

The shrub layer was heavily modified by development. Significant negative correlations ($P < 0.01$) were found between the development index and the total number of shrubs, the number of deadfalls, shrub snags, as well as with a number of groups of shrub species. Shrub species negatively affected by development ($P < 0.01$) included balsam fir, eastern hemlock, striped maple *(Acer pensylvanicum)*, mountain maple *(Acer spicatum)*, red maple, sugar maple, hobblebush *(Viburnum alnifolium)* northern wild raisin *(Viburnum cassinoides)*, common winterberry holly *(Ilex verticillata)*, sweet gale and leatherleaf *(Chamaedaphne calyculata)*. The only shrub species showing an increase with development was white spruce *(Picea glauca)*. The shrub component of the vegetation was generally modified over a larger area than the tree component and there appeared to be more selection in the type of shrub species removed.

The removal of tree and shrub vegetation also affected ground species probably by altering the microclimate close to the ground. Significant negative correlations ($P < 0.01$) were established between the DI and variables such as moss cover, ferns *(Pteridopyta)* and starflowers *(Trientalis borealis)*. These vegetation variables may indicate a stable, moist

microclimate which can be an important factor influencing small mammal populations, particularly the red-backed vole (Getz 1968; McManus 1974). The introduction of large expanses of short grass by cottagers can also inhibit the movement of small mammals (Cole 1978).

Aquatic habitat is significantly ($P < 0.01$) altered by development through the reduction of aquatic snags, submergent and floating vegetation and overhanging shrub and tree vegetation. Significant ($P < 0.01$) changes were noted in the quantity of shoreline vegetation and in the substrate homogeneity as a result of the construction of sand beaches and the removal of large stones.

8.4.2 DENS

Fifty-two of the 59 mink dens were found on undeveloped shorelines. Dens were frequently found in areas with good horizontal cover. Foliage board measures at 3.5 m from the den indicated that 31.4 percent of the foliage board was obscured by vegetation from that distance. The coniferous composition in the circle around the den averaged 76 ± 26 while the average for the 94 vegetation plots sampled was much lower (47 ± 32). The dens were also located in areas with higher than average shrub densities, deadfalls, stumps and number of tree individuals ($P < 0.01$). All of these variables were found to decrease on developed shorelines. The shrub coverage values were higher ($P < 0.05$) at 1.0 m from the den than they were at 3.5 m from the den. This might indicate a preference of a dense shrub layer at the entrance to the den itself. Since a number of dens may be used by one mink (Schladweiler and Storm 1969) and dens were frequently the source of a large number of scats, habitats with a large number of scats should indicate good denning habitat.

8.4.3 SHOREWALKING

A total of 1,321 mink scats were collected in the nine categories of coniferous composition and development (Table 8.4). Mink activity was greatest on coniferous and mixed shorelines with little or no development whereas deciduous shorelines were not used much regardless of development levels (Fig. 8.2). The number of scats found in a habitat type was assumed to be proportional to the amount of time spent by mink there. Gerell (1969) noted that, within a period of activity, mink moved to and fro within restricted areas which usually did not exceed 300 m and that the occasional travel between these core areas was rapid (Gerell 1970). Gerell (1970) also suggests that the main reason for the irregularity of intensity of home range use may be the distribution of available food and hunting places. Therefore, it is improbable that a large number of scats would be found in an area not used for intensive hunting. Also, the habitat types (deciduous, coniferous and mixed), were usually found along extensive lengths of shoreline with the north and west shores of lakes predominantly deciduous and the south and east shorelines predominately coniferous. Likewise, cottage development frequently existed in a long, continuous ribbon along lengths of shoreline. Small localized developments were uncommon.

Although overgrown areas were intensively searched, most of the scats were found on mossy hummocks, rocks, stumps or fallen logs in relatively sheltered habitats, while some scats were found on fully exposed rocks and cottagers docks (Fig. 8.3).

The visibility of the scats may be attributed to a preference for conspicuous scent posts, visual territorial stimuli, open runways or travel lanes. Marshall (1936) noted that mink tracks were usually found along small paths where thick clumps of brush or sedge could be avoided. This behaviour increases the visibility of any scats. Almost 90% of a mink's active time is spent hunting while the greatest intensity of use of the home range occurs in areas of occupied dens (Gerell 1970). Since the study was undertaken before the annual juvenile dispersal, information was obtained on habitat selection during this important period.

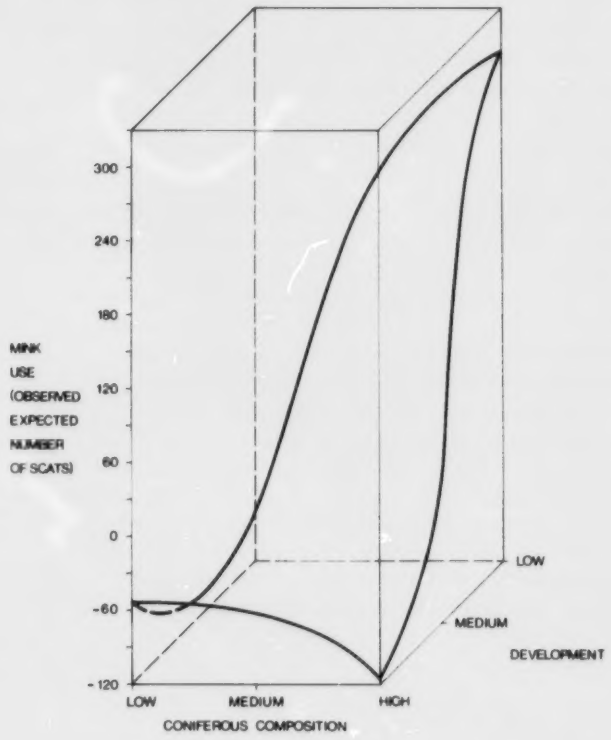

Figure 8.2 Three-dimensional illustration of mink use patterns with respect to coniferous composition of habitat and level of development. Mink use is a relative value based upon the difference between the observed and the expected number of scats in each of the habitat and development categories.

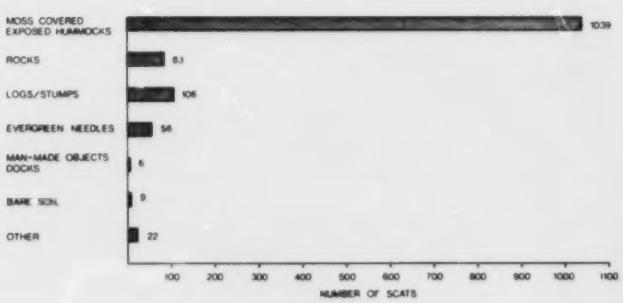

Figure 8.3 Frequency histogram of the number of mink scats found on each of seven different locations. The category labelled as moss covered hummocks includes all exposed moss covered stumps, rocks, and upraised clumps of soil.

A significant ($P < 0.05$) negative regression between mink density (number of scats/unit effort of search) and CLDI was established with data from seven lakes which were completely searched in 1978 (Fig. 8.4). This index of mink activity was used because two lakes were only searched twice while the others were searched three times. The decrease in activity was probably due to the reduction of available food, hunting locations or suitable denning sites. The relationship in Figure 4 was a modifying bias in that the undeveloped lakes were very difficult to shorewalk and a large proportion of the time and effort was consumed by recording and labelling scats found. Therefore at low levels of development, mink activity was probably much higher than indicated. Likewise, at high levels of development, walking was made easier by simplified shorelines and the number of scats found per unit effort was probably estimated at a higher level than it should have been. Removal of this bias would increase the strength of the negative relationship between mink activity and cottage development.

The mink activity factor was used as a dependent variable in a stepwise multiple regression using selected variables from the principal component reduction. A significant ($P < 0.001$) relationship was established between mink activity and the variables representing the first two principal components: the Development Index and the percentage of coniferous composition of the tree layer (Fig. 8.5). The largest mink activity factor is predicted at high levels of coniferous composition and low levels of development. This should indicate good areas for denning and raising young. A best-fitting non-linear regression was used to investigate the non-linear properties of the relationship between mink activity and the Development Index (Fig. 8.6). The relationship shows a rapid decline in mink activity with a relatively small increase in development from the undeveloped state.

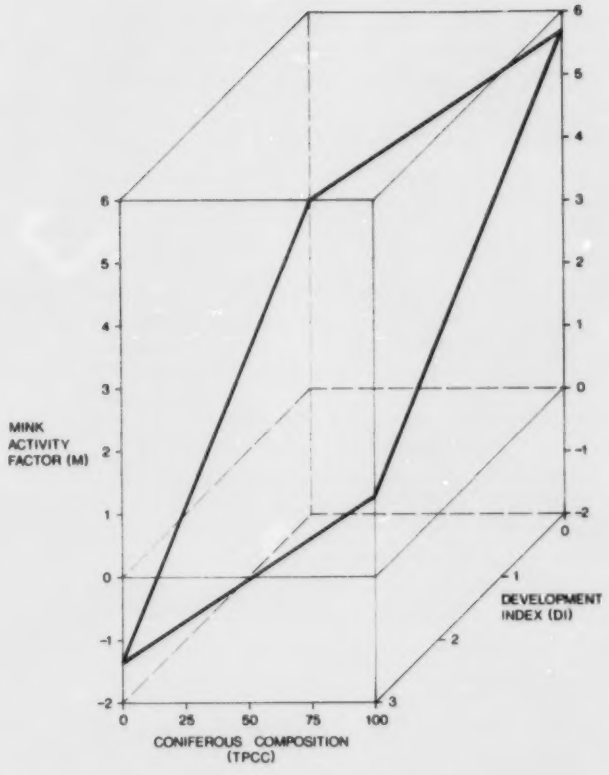

Figure 8.5 The linear response surface of the mink activity factor (M) to the development index (DI) and the coniferous composition of the tree layer. The prediction equation $M = 3.005 - 1.468\ (DI) + (TPCC)$ is significant ($P < 0.001$).

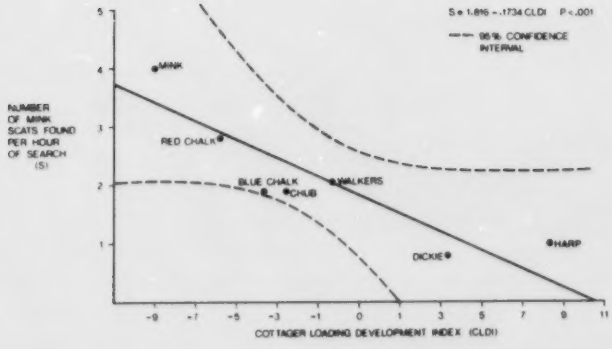

Figure 8.4 Relationship between relative mink activity(S) and the Cottage Loading Development Index (CLDI) based on the ratio of developed to undeveloped shorelines. The dotted line represents a 95% confidence interval on the slope calculated by Thiel's nonparametric techniques (Hollander and Wolfe 1973).

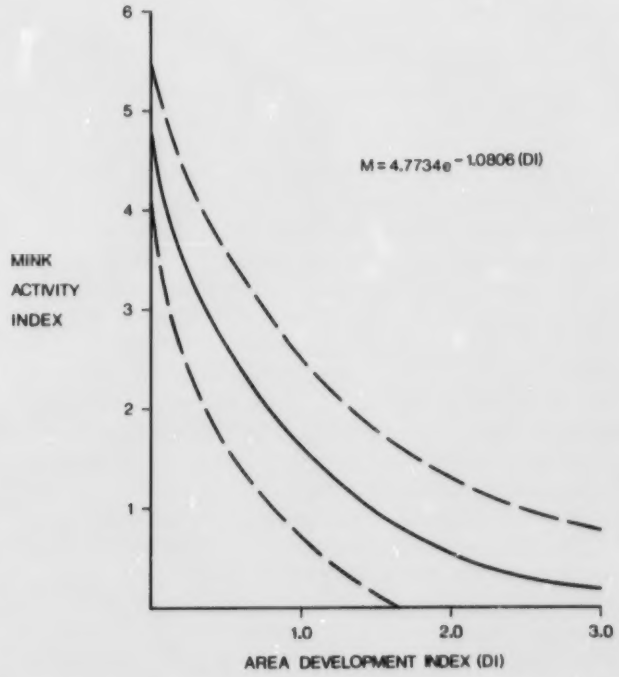

Figure 8.6 Relationship between mink activity and the intensity of cottage development. The solid line represents the predicted values and the dotted lines represent the standard deviation of the observed values.

8.4.4 FOOD HABITS

The percent occurrence of major classes of food items was calculated for the scats found. (Fig. 8.7). These results were compared (Table 8.5) with another frequency of occurrence analysis of 561 scats by Hamilton (1959). The frequency of occurrence analysis was very similar in all food item categories despite the fact that many of the scats analyzed in Hamilton (1959) were collected in marsh areas. (Extensive wetlands were avoided in this study since they are generally unsuitable for cottage development.) Gerell (1968) found that waterfowl formed the most important food item in the avian category in many of the areas he studied in Sweden. The absence of marshland and, therefore, of high quality waterfowl breeding habitat, may explain the low incidence of birds in the diet of mink on the lakeshores studied.

Studies by Dearborn (1932), Sealander (1943), Hamilton (1936, 1940, 1959), Guilday (1949), Wilson (1954), Korschgen (1958) and Gerell (1967, 1968) indicate the food habits of mink are variable and depend, to a large degree, upon season and habitat. The difference in intake of each of the food items was tested over the three levels of both coniferous composition and development by means of chi square tests (Fig. 8.8).

Small mammal intake was not dependent on ($P < 0.001$) coniferous composition but was independent of levels of development. The high intake of mammals in mixed forests probably reflects the ability of the mixed forest to sustain large populations in diverse small mammal communities. The mixed forest also provides a greater diversity of hunting locations and microhabitats than do deciduous or coniferous shorelines. Common small mammals found in the Study area were the deer mouse *(Peromyscus maniculatus)* and the Boreal red-backed vole *(Clethrionomys gapperi)*, both of which decreased with increased development (Racey and Euler, 1982). Other species increased in areas of high development, particularly the meadow vole *(Microtus pennsylvanicus)* and the eastern chipmunk *(Tamias striatus)*. The most dense and diverse small mammal communities existed on mixed shorelines with very little development (Racey and Euler, 1982), which coincides with the maximum use of small mammals by mink (Fig. 8.8). Some of the more prevalent small mammal species occurred in mink scats only at high levels of development. Specific changes in small mammal composition can be detected only if prey items are identified by species. Little change was noted in the use of fish in the three different levels of coniferous composition. Significant ($P < 0.001$) percentage differences in the occurrence of fish in the diet exist in the three levels of development. Mink may enter water in search of prey for two reasons; terrestrial prey becomes more difficult to capture than aquatic prey or there is a greater ability to exploit aquatic prey (Dunstone 1978). Small fish tend to be attracted to docks, particularly rock crib docks, probably in a response similar to that outlined by Smith and Tyler (1973) in their experiments with artificial reefs.

Mink respond to a capture in the vicinity of a refuge by an increased investigation of that area (Dunstone 1978). If fish are always located within a refuge, a focus for searching behaviour is established, allowing the development of specific search strategies. The building of docks, particularly of the rock-crib style, and the simplification of the shoreline by cottagers through the removal of aquatic snags and the

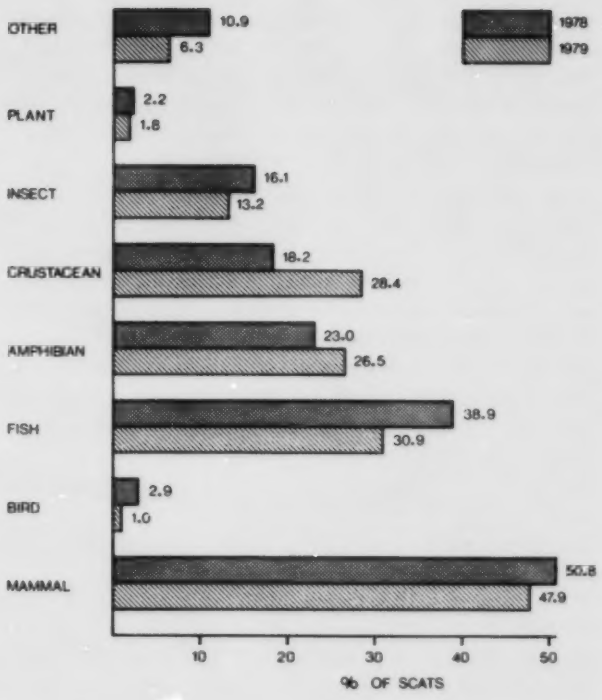

Figure 8.7 Percentage of scats containing each food item, illustrating similarity between years.

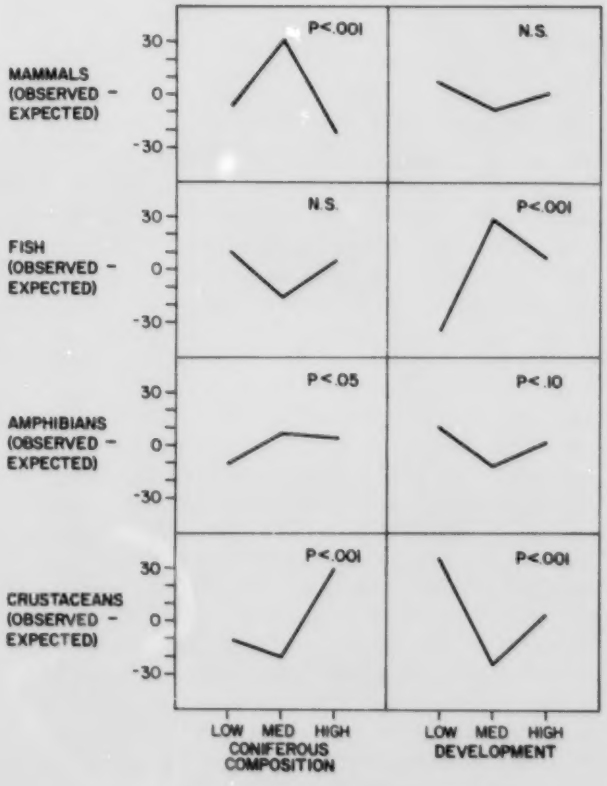

Figure 8.8 Variations in the occurrence of food items in scats with respect to habitat type and levels of development. A chi square test of independence was calculated for the observed and expected number of scats in each habitat or development category.

clearing of large areas of submergent, emergent and floating vegetation, would tend to create a more patchy environment and concentrate fish in smaller areas easily recognized and hunted by mink. At extremely high levels of development, the lack of cover near the shoreline becomes so acute that other food sources might be easier to exploit.

Gerell (1968) noted a conspicuous interaction between the level of consumption of mammals and fish, and found that fish were taken predominantly in the winter months. Mink appear to choose between hunting in the aquatic or terrestrial habitats on the basis of food availability and other extraneous factors. These factors may include the age and size of the animals. For example, the young of the year, concentrated in good denning areas, will choose easier prey like crustaceans while adults may choose that which is more difficult. It is unlikely that mink exploit both feeding regimes in the same hunting session. This is supported by the hunting strategy of mink described by Dunstone (1978).

Amphibians were preyed upon at varying intensities according to the degree of coniferous composition ($P<0.05$) and the development ($P<0.10$). Gerell (1969) explained that the spring peak consumption of amphibians by mink was due to the increased activity of amphibians in their spring breeding period. Gerell also noted that the abundance of frogs in the diet was apparently correlated with the declining availability of rodents or to their principal food items. In our area, at the time of this study, six prominent species of amphibians were breeding: the wood frog *(Rana sylvatica)*, western chorus frog *(Pseudacis triseriata triseriata)*, spring peeper *(Hyla crucifer)*, the American toad *(Bufo americanus)*, and the spotted salamander *(Ambystoma maculatum)*. Most of the amphibian remains in the scats were extremely small, probably belonging to chorus frogs, spring peepers or salamanders.

The number of scats with crustacean remains varied significantly ($P<0.001$) with the coniferous composition and development levels of the area in which they are found. Gerell (1968) explains that the high incidence of crustaceans in the diet of mink during the warmer months is due to a corresponding increase in crustacean activity. Shallow water or the lack of refuge may also affect the susceptibility of crayfish to mink predation (Gerell 1968). The abundance of crayfish is also an important consideration in the number taken by mink. There are seven species of crayfish in the study area. The most cosmopolitan was *Orconectes propinquus*. This species can be found in any aquatic habitat in the area that has surface stones under which the crayfish can hide (Berrill 1979). A common requirement for crayfish species is the existence of protective shelter. Cottage development tends to reduce the complexity of the aquatic portion of the shoreline as large stones, snags and aquatic vegetation are removed and sand beaches are introduced. This simplification of the shoreline could reduce the size of the crayfish population in developed areas through a reduction in the availability of shelter and hiding spots. Likewise, increasing shoreline complexity will increase crayfish populations (Burgess and Bider 1980). Crustaceans may also be easier to catch by young mink, thereby increasing the exploitation of this food item in coniferous areas near dens. Interaction was evident between the use of crustaceans and the use of fish by mink in the three development categories and between crustaceans and mammals in the coniferous composition categories. These results reflect the complex response of the mink, an opportunistic predator, to food availability.

There were no significant differences noted in the use of insects, birds or plant matter by mink. Birds were sparingly used as a food source for reasons previously discussed. Gerell (1968) states that water insects were seldom used in most of his study area. It is apparent that the choice of prey by mink depends on the abundance of major food items and that the resulting distribution of mink is affected significantly by the availability of food. This would seem to be consistent with the hypothesis that the selection of habitat by mink is based on the available food supply. This is verified by Gerell (1969) who noted that the activity peaks of male mink corresponded to those of prey activity.

The results of this study indicate that shoreline cottage development has a directly detrimental effect upon the habitat of mink. Changes in the habitat have an impact on food availability which, in turn, affects the ability of that habitat to support large mink populations.

Mink require areas of dense cover for dens which were provided by areas of high coniferous composition and low development. Most of the hunting was probably carried out near areas of occupied dens, particularly by females and young of the year.

The intake of any particular food item was dependent in part upon its abundance and the availability of alternative food sources. The mink, as an opportunistic predator, reflects changes in the abundance and availability of prey in its diet. Therefore, a decline in the mink activity on a shoreline is the result of changes in natural prey populations brought about by alteration of the vegetative component of the habitat.

The Development Index and the mink activity factor both reflect a gradient of habitat disturbance. Therefore, it is possible to use these measures as an indication of the environmental impact of cottage development. The Cottage Loading Development Index is an acceptable indicator of mink activity. Levels of the CLDI greater than 1.0 may be said to have an undesirable impact on mink populations.

8.5 ACKNOWLEDGEMENTS

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9. SMALL MAMMAL AND HABITAT RESPONSE TO SHORELINE COTTAGE DEVELOPMENT IN CENTRAL ONTARIO

G. RACEY and D. EULER

9.1 SUMMARY

Changes in small mammal abundance and habitat caused by shoreline cottage development in central Ontario were studied in the summers of 1978 and 1979. This development significantly altered the vegetation composition and structure in the vicinity of cottages. These alterations, in turn, had an impact on small mammal abundance. These animals were classified in three response categories; tolerant (existing, at some level, regardless of degree of development), intolerant (extirpated at high levels of development), and indifferent to development. Tolerant species were the eastern chipmunk *(Tamias striatus)*, short-tailed shrew *(Blarina brevicauda)*, and deer mouse *(Peromyscus maniculatus)*; intolerant species were the masked shrew *(Sorex cinereus)*, redback vole *(Clethrionomys gapperi)* and woodland jumping mouse *(Napeozapus insignis)*. The red squirrel *(Tamias-curus hudsonicus)* was indifferent to development. Small mammal diversity was highest on mixed shorelines at moderate levels of development. Species diversity appeared to respond positively to vegetative composition, edge effect, and irregularity of habitat. These characteristics were all dependent on the level of cottage development.

9.2 INTRODUCTION

Cottage development in central Ontario occurs primarily along lakeshores and waterways. Because this riparian habitat is a finite resource, an evaluation of the effects of cottage development on it and the wildlife species it supports is essential to planning.

Small mammals are important components of the terrestrial food web. They function as first and second level consumers, and as a food source for predators. Changes in their numbers can indicate alterations in energy flow and trophic structure (Golley et al. 1975). Therefore, small mammals can be good indicators of environmental impact. Measuring their response to cottage development is an important step in the study of its overall impact on wildlife.

The effects of human recreational activity or development on small mammals or on their habitat has been briefly examined, including the impact of campgrounds (Clevenger and Workman 1977), winter roads (Douglass 1977), and mowed strips of grassland (Cole 1978). Chipmunks have been specifically studied in residential environments (Ryan and Larson 1976). The adverse effects of recreational activity on habitat have also been documented (McQuaid-Cook 1978; Weaver and Dale 1978).

Numerous studies have identified relationships between habitat alterations and small mammal numbers. These habitat changes have included: old field succession (Hirth 1959), regeneration of land subjected to strip-mining (Hansen and Warnock 1978), burning (Krefting and Ahlgren 1974; Buech et al. 1977) and clear-cutting (Sims and Buchner 1973; Kirkland 1977). Other general investigations of small mammal/habitat relationships involved the study of microclimate requirements (Pruitt 1959; Hayward 1965; Getz 1968) and microhabitat selection (Kirkland and Griffin 1974; M'Closkey and Fieldwick 1975; M'Closkey 1976; Morris 1979). However, little is known of changes in small mammal numbers caused by cottage development.

The purpose of this paper is to describe the impact of shoreline cottage development on the abundance and distribution of small mammals in central Ontario and to relate these impacts to alterations in vegetative composition and structure.

9.3 METHODS

Study plots were situated on the shorelines of 15 lakes chosen within a 50 km radius of the village of Dorset in the Haliburton Highlands area of central Ontario (Fig. 9.1). Precambrian igneous rock formations are the predominant physiographic features. Coniferous shorelines are comprised primarily of white cedar *(Thuja occidentalis)*, eastern hemlock *(Tsuga canadensis)*, and white pine *(Pinus strobus)*. Deciduous shorelines contain white birch *(Betula papyrifera)*, bigtooth aspen *(Populus grandidentata)*, and sugar maple *(Acer saccharum)*. Backshore areas are dominated by red maple *(Acer rubrum)*, red oak *(Quercus ruba)*, and American beech *(Fagus grandi-folia)*. A coniferous fringe is present, to some extent, on most shorelines, but is most pronounced on those which are north and east-facing. It primarily contains eastern hemlock, white cedar and balsam fir *(Abies balsamea)*.

Fifty-six plots, each 50 x 50 m, were live-trapped for small mammals in July and August of 1978 and 1979. Shorelines were classified according to a degree of coniferous composition (deciduous, mixed, or coniferous), and level of cottage development (low, medium, and high). The plots were distributed as evenly as possible at each level of coniferous composition and cottage development. All study plots were located on uniformly sloping shorelines with 2.5 to 45% slope. A grid of 36 Sherman LFA traps (9 x 8.5 x 23 cm) was established on the corners of nine subplots locatd on each plot

Figure 9.1 Map of the study area located in the Muskoka — Haliburton region of central Ontario.

(Fig. 9.2). Three trapping periods of three nights each provided 324 trap-nights per plot per year. The traps were baited with a mixture of rolled oats, peanut butter and skim milk powder, and were provided with polyethylene fibre for bedding material. Traps were checked between 0600 and 1100 each morning.

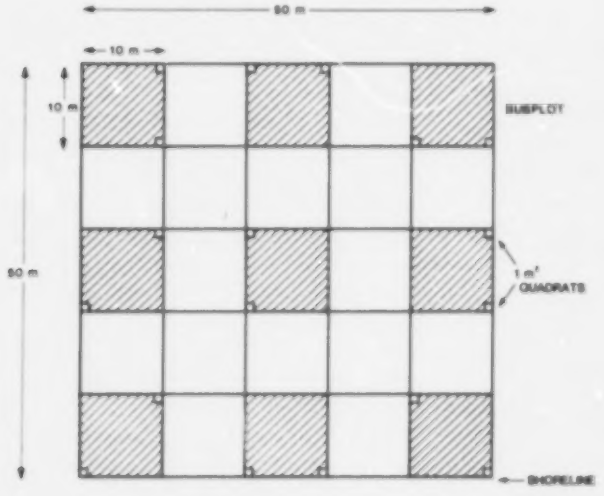

Figure 9.2 Schematic diagram of a plot on which small mammals were captured in 36 traps set on the corners of 9 subplots. Tree and shrub vegetation was sampled on the subplots and ground vegetation was sampled in two quadrats of 1.0 m^2 randomly positioned on the corners of each subplot.

Numbered fingerling tags were used to ear tag all animals captured; except the masked and short-tailed shrew. Data on sex, reproductive condition, length, weight, and ear tag number were recorded for all captures, and all animals were released at the point of capture. Relative population size of each species was estimated by means of a Capture Index (CI) for each plot.

$$CI = \text{number of captures}/324 \text{ trap-nights} \quad (1)$$

Small mammal species diversity was calculated for each plot, using the number of captures, by Shannon's index (Wilhm and Dorris 1968).

Vegetation was sampled on nine subplots, each 10 x 10 m, systematically distributed over each main plot. Trees (> 10 cm dbh) and shrubs (< 10 cm dbh) were counted in the subplots and ground vegetation and seedlings were evaluated in 1.0 m^2 quadrats, randomly positioned on two corners of each of the nine subplots (Fig. 9.2). Species with similar growth forms, habitat associations, or close generic ties in the tree, shrub and ground layer were classified according to 22, 38 and 50 variables respectively. These variables and 17 structural parameters were measured on each subplot. Those variables and parameters that were significantly correlated with development are listed in Table 9.1.

Table 9.1 Names of functional vegetation groups and significant correlations with the Development Index (DI) on deciduous (D), mixed (M), and coniferous (C) shoreline plots.

Group Name	Representative Species in Group	Sign of Significant Correlations D	M	C
Ground Vegetation				
AST	large-leaved aster *(Aster macrophyllus)*, purple stemmed aster *(A. puniceus)*	−		
	northern bedstraw *(Galium boreale)*, fragrant bedstraw *(G. triflorum)*			
	boneset *(Eupatorium perfoliatum)*, spotted joe-Pye-weed *(E. maculatum)*			
BUCK	buckwheat *(Fagopyrum sagittatum)*, climbing false buckwheat *(Polygonum scandens)*		+	
BUN	bunchberry *(Cornus canadensis)*			−
BUT	common buttercup *(Ranunculus acris)*, marsh-marigold *(Caltha palustris)*, baneberry *(Actaea* spp.*)*			
CHIC	common chickweed *(Stellaria media)*, mouse-ear chickweed *(Cerastium vulgatum)*	+		
CLIN	clintonia *(Clintonia borealis)*			
CUC	Indian cucumber-root *(Medeola virginiana)*			
CREEP	creeping snowberry *(Gaultheria hispidula)*, trailing arbutus *(Epigaea repens)*			
DAISY	ox-eye daisy chicory *(Chrysanthemum leucanthemum)*, chicory *(Cichorium intybus)*	+		
DOG	spreading dogbane *(Apocynum androsaemifolium)*			

Table 9.1 Continued

Group Name	Representative Species in Group	Sign of Significant Correlations D	M	C
Ground Vegetation				
DUT	Dutchman's-breeches (*Dicentra cucullaria*), squirrel-corn (*D. canadensis*)			
FIRE	fireweed (*Epilobium angustifolium*)			
GER	herb-Robert (*Geranium robertianum*), Bicknell's cranesbill (*G. bicknellii*)			
GOLDR	species of goldenrod (*Solidago* spp.)			
GOLDT	goldthread (*Coptis groenlandica*)			
HAWK	species of hawkweed (*Hieracium* spp.)		+	+
HEP	species of hepatica (*Hepatica* spp.)			
IND	Indian pipe (*Monotropa uniflora*), species of sundew (*Drosera* spp.), pitcher-plant (*Sarracenia purpurea*)			
IRIS	iris (*Iris* spp.)			
JEW	species of jewelweed (*Impatiens* spp.)			
LETT	Canada thistle (*Cirsium arvense*), common dandelion (*Taraxacum officinale*), smooth white lettuce (*Prenanthe racemosa*), common plantain (*Plantago major*)	+	+	
MAY	Canada mayflower (*Maianthemum canadense*)	−		
MAL	mallows (*Malvaceae* spp.)			
MINT	nettles (*Urticaceae* spp.) erect bugle (*Ajuga genevensis*), catnip (*Nepeta cataria*)	+		
ORCH	moccasin-flower (*Cypripedium acaule*), round-leaved orchis (*Habenaria orbiculata*)			
TAX	american yew (*Taxus canadensis*), trailing juniper (*Juniperus horizontalis*)			
PEA	clovers (*Trifolium* spp.), trefoils (*Lotus* spp.)		+	
PRIM	common evening primrose (Oenothera biennis), yellow loosestrife (*Lysimachia terrestris*)			
SAX	saxifrages (*Saxifraga* spp.), foamflower (*Tiarella cordifolia*)			
SPEE	common speedwell (*Veronica officinalis*), bird's-eye Speedwell (*V. Chamaedrys*)			+
SOL	Solomon's-seal (*Polygonatum biflorum*), false Solomon's seal (*Smilacina racaemosa*)	−		
STAR	starflower (*Trientalis borealis*)	−	−	
STRAW	strawberries (*Fragalia* spp.)	+	+	
STJON	common St. Johnswort (*Hypericum perforatum*)			
VIOL	violets (*Viola* spp.)			
WINT	wintergreen (*Gaultheria procumbens*)	−		
WOOD	wood sorrels (Family *Oxalidaceae*)			−
YARROW	yarrow (*Achillea millefolium*)			
RUB	raspberries (*Rubus* spp.)			
SARS	bristly sarsaparilla (*Aralia hispida*)	−	−	
VACC	mountain cranberry (*Vaccinium vitis-idaea*), blueberries (*Vaccinium* spp.)			
FERN	ferns (*Polypodiaceae*)	−	−	
MOSS	mosses (*Bryophyta*)			
LICH	lichens (*Thallophyta*)			
CLUB	clubmosses (*Lycopodiaceae*)			
GRAS	grasses (*Graminaceae*)	+	+	
ROCK	percent of quadrat taken up by rock			
CSEED	number of coniferous seedlings on quadrat			
DSEED	number of deciduous seedlings on plot	−	−	−
Shrub Vegetation				
ALNUS	speckled alder (*Alnus rugosa*), smooth alder (*A. serrulata*)			−
AMEL	juneberries (*Amelanchier* spp.)			
COAL	alternate-leaved dogwood (*Cornus alternifolia*), round-leaved dogwood (*C. rugosa*)			
SABIE	balsam fir (*Abies balsamea*)	−	−	−
SACERP	striped maple (*Acer pennsylvanicum*), mountain maple (*A. spicatum*)	−	−	−
SACERS	red maple (*A. rubrum*), sugar maple (*A. saccharum*)		−	−
SBETL	yellow birch (*Betula alleghaniensis*)			
SBETP	white birch (*Betula papyrifera*)			
SFAG	beech (*Fagus grandifolia*)			−

Table 9.1 Continued

Group Name	Representative Species in Group	Sign of Significant Correlations D	M	C
Shrub Vegetation				
SFRAXA	white ash (*Fraxinus americana*)			
SFRAXN	black ash (*Fraxinus nigra*)			
SLARI	American larch (*Larix laricina*)	+		
SOST	hornbeam (*Ostrya virginiana*), ironwood (*Carpinus caroliniana*)			
PRUN	choke-cherry (*Prunus virginiana*), pin cherry (*Prunus pennsylvanica*)			
PYR	American mountain ash (*Sorbus americana*)			
RHUS	staghorn sumac (*Rhus typhina*)			
RIBE	gooseberries (*Ribes* spp.)			
SAMB	common elderberry (*Sambucus canadensis*), red elderberry (*S. pubens*)			
SPIR	steeplebush (*Spiraea tomentosa*), meadowsweet (*S. latifolia*)			
TAX	american yew (*Taxus canadensis*), trailing juniper (*Juniperus horizontalis*)			
VIB	nannyberry (*Viburnum lentago*), northern wild raisin (*V. cassinoides*) hobblebush (*V. alnifolium*)	−	−	−
COST	red osier dogwood (*Cornus stolonifera*)			
CORY	beaked hazelnut (*Corylus cornuta*)			
LED	Labrador-tea (*Ledum groenlandicum*), bog rosemary (*Andromeda glaucophylla*)			
LONI	Canada honeysuckle (*Lonicera canadensis*), northern bush honeysuckle (*Diervilla lonicera*)			
MYR	sweet gale (*Myrica gale*), leatherleaf (*Chamaedaphne calyculata*)	−		
SPICEA	white spruce (*Picea glauca*), red spruce (*Picea rubens*)	+	+	
SPINU	white pine (*Pinus strobus*), red pine (*Pinus resinosa*)			
SPOPUL	bigtooth aspen (*Populus grandidentata*), trembling aspen (*P. tremuloides*)			
SPRUN	black cherry (*Prunus serotina*)			
SQUER	red oak (*Quercus rubra*)	−		
SSALIX	willows (*Salix* spp.)			
STHUGA	white cedar (*Thuja occidentalis*)		+	
STSUGA	eastern hemlock (*Tsuga canadensis*)			−
STILI	basswoods (*Tilia* spp.)			
SULMU	American elm (*Ulmus americana*), slippery elm (*U. rubra*)			
STUMP	number of stumps on subplot	−	−	
SSNAG	number of dead plants of shrub size	−	−	−
Tree Vegetation				
ABIE	balsam fir		−	−
ACERP	striped maple, mountain maple			
ACERS	red maple, sugar maple	−	−	−
BETL	yellow birch			−
BETP	white birch	−	−	+
FAG	beech			
FRAXA	white ash			
FRAXN	black ash			
LARIX	American larch			
OST	hornbeam, ironwood			
PICEA	white spruce, red spruce			
PINUS	white pine, red pine		+	
POPUL	bigtooth aspen, trembling aspen			
PRUN	black cherry			
QUERC	red oak			
SALIX	willows			
THUJA	white cedar		−	
TSUGA	eastern hemlock			
TILIA	basswoods			
ULMUS	American elm, slippery elm			
DEDF	number of deadfalls > 10 cm dia. on subplot	−	−	−
SNAGS	number of dead plants of tree size	−	−	−

Table 9.1 continued

Group Name	Representative Species in Group	Sign of Significant Correlations D	M	C
GFHD	ground coverage, sum of 4 presence-absence measures of shrub vegetation on quadrats			–
TFHD	tree coverage, sum of 4 presence-absence measures of tree vegetation on quadrats	–	–	–
GVOL	percent foliage volume of ground vegetation (< 1.5 m) on quadrats	–	–	
SVOL	percent foliage volume of shrub vegetation (1.5 m < height < 9.0 m) on quadrats		–	
TVOL	percent foliage volume of tree vegetation (> 9.0 m canopy height) on quadrats	–	–	
FHD	foliage height diversity using Shannon's index on GFHD, SFHD, TFHD	–	–	–
PVV	percent vegetation volume - sum of GVOL + SVOL + TVOL	–	–	
VOLDIV	volume diversity (PCVV x FHD/3)	–	–	
SPCC	percent conifer composition of shrubs	+	+	
SSPDIV	shrub species diversity calculated by Shannon's index from functional groups	–	–	
SSP	number of shrub functional groups			
TOTSHR	number of shrub individuals	–	–	–
TPCC	percent conifer composition of trees	ND	ND	ND
TSPDIV	tree species diversity calculated by Shannon's index from functional groups	–	–	
Parameters				
TSP	number of tree functional groups represented	–	–	–
TOTRE	number of tree individuals	–	–	

Development was measured using a Development Index (DI):

$$DI = (Ag + As + At)/Area \quad (2)$$

where: Ag = area disturbed in the ground layer
As = area disturbed in the shrub layer
At = area disturbed in the tree layer
Area = total area of the plot.

The DI had a value of 3.0 when all vegetation on the plot was disturbed by cottage development. A section of a vegetation layer was considered disturbed if a building or other man-made object occupied it, or if human activity had halted natural succession, and/or returned, and maintained the area at an earlier successional stage. For data analysis, the plots were divided into three groups of a similar size, based on degree of coniferous composition. The 33rd and 66th percentiles of the TPCC (percent conifer composition of the tree layer) variable were used as the distinguishing criteria. Deciduous plots had a TPCC < 10.5%; and coniferous plots TPCC > 42.5%. A similar procedure was used to divide plots into three different levels of development (low DI < 0.033), medium (0.033 < DI < 2.25), and high (DI > 2.25).

Correlations between development and vegetation variables were calculated for each habitat type. The relationship between coniferous composition of the subplots and the dsitance from shore was also investigated by correlation analysis. A best-fitting prediction equation was established between the Capture Index for each animal species and the Development Index. These equations were established as polynomial regressions or non-linear decay functions. A stepwise multiple regression procedure (Dixon 1975) was used to describe the habitat chosen by each species.

Since it was necessary to reduce the number of variables for this procedure, the redundant or irrelevant variables were discarded, using the multivariate techniques described by Beale et al. (1967) and Jolliffe (1972). A principal component analysis examined the axes of variability in the reduced data set, including the capture data. Discriminant function analysis was used to illustrate ecological separation of small mammal species, using the 17 habitat parameters and the Development Index.

9.4 RESULTS

The vegetation parameters and capture results were subjected to a principal component analysis to determine the major axes of biological variability between the study plots. The first component described the vertical foliage distribution, using the percent vegetation volume (PVV), foliage height diversity (FHD), and vegetation volume diversity (VOLDIV). The second principal component described the amount of vegetation clearing that was due to cottage development. The positive end of this component was represented by the number of tree individuals (TOTRE) and the number of tree functional groups (TSP); the negative end, by the DI. The third component, which identified the coniferous composition of the habitat, involved the following variables: percent conifer composition of shrubs (SPCC), and percent conifer composition of trees (TPCC) at the negative end of the axis; ground vegetation volume (GVOL), shrub vegetation volume (SVOL), and number of shrub functional groups (SSP) at its antipode. The effect of the variability in the data, due to the level of coniferous composition, was reduced by analysing the data collected in each habitat type separately.

Significant ($P < 0.1$) correlations between vegetation and development occurred in all three types (Table 9.1). Increased development produced decreases in shade-loving species, and increases in early, and mid-successional, or alien species. Most groups of plants of shrub size, that were significantly altered by development, had negative correlations with the Development Index.

Trees also decreased with cottage development and the number of deadfalls and snags of tree size decreased on all shorelines. Tree, shrub, and ground cover, and their respective volume values decreased with development in, at

least, one habitat type as did FHD, PVV, and VOLDIV (Table 9.1).

All shorelines exhibited a coniferous fringe to some extent. Therefore, it was very difficult to establish a strictly deciduous study plot. A significant, negative ($P < 0.01$) correlation was established between the percent conifer composition and the distance of the subplot from the shoreline on deciduous and mixed shorelines.

Trapping on the 56 plots yielded 2,013 animal captures in 18,144 trap nights for an 11.1% success rate. Degree of success ranged from 37.6% on an undeveloped, mixed plot to 3.9% on a highly developed, deciduous plot. The number of captures per species was as follows: masked shrew 30; smoky shrew *(Sorex fumeus)* 6; short-tailed shrew 112; meadow vole *(Microtus pennsylvanicus)* 10; woodland jumping mouse 48; deer mouse 843; redback vole 320; eastern chipmunk 590; and red squirrel 54. The relative number of each species changed with the DI Index (Fig. 9.3). Of the species that appeared to increase with development, the chipmunk

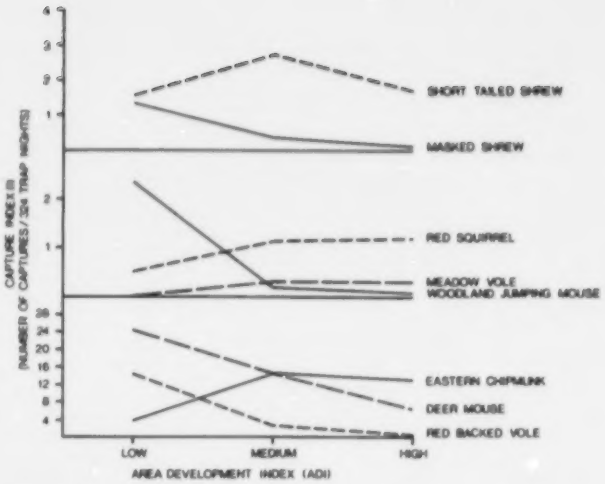

Figure 9.3 Plot of the Capture Index of each species studied versus three levels of the Development Index.

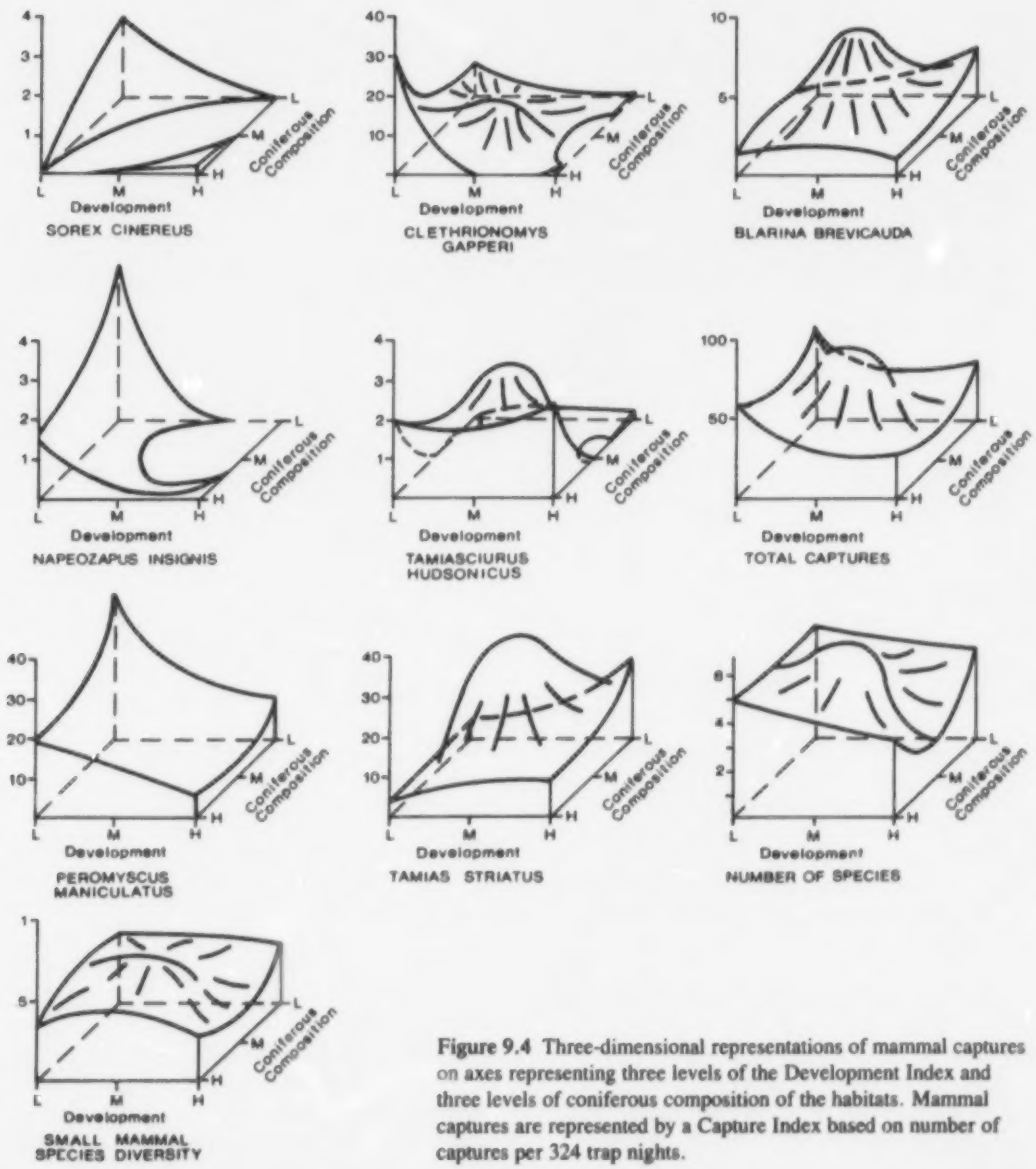

Figure 9.4 Three-dimensional representations of mammal captures on axes representing three levels of the Development Index and three levels of coniferous composition of the habitats. Mammal captures are represented by a Capture Index based on number of captures per 324 trap nights.

increased in number significantly ($P < 0.01$), while the red squirrel and meadow vole populations underwent significant changes. The short-tailed shrew appeared to be most successful at moderate levels of development. Species which were negatively correlated with development were masked shrew ($P < 0.05$), deer mouse, red-back vole and woodland jumping mouse ($P < 0.001$).

Too few smoky shrews were captured to establish a relationship with development. Species diversity exhibited a significant ($P < 0.01$) negative correlation with the DI.

Two types of response were observed in the three-dimensional representations of the Capture Index (CI) for each species to the three levels of development and habitat types (Fig. 9.4). The masked shrew, woodland jumping mouse, red-back vole and deer mouse exhibited fairly steep and uniform declines on the axes of development, coniferous composition, or both. The short-tailed shrew, eastern chipmunk, and red squirrel had the largest CI on mixed shorelines at moderate levels of development. The total number of captures, number of species captured, and species diversity also had maximum values under the same conditions.

Table 9.2 Results of Principal Components Analysis on 18 vegetation and development measures and 8 small mammal species.

	PRINCIPAL COMPONENT			
Variable	I	II	III	IV
VOLDIV	0.915	0.0	0.0	0.0
PVV	0.907	0.0	-0.275	0.0
TVOL	0.860	0.0	0.0	0.0
SVOL	0.841	0.0	0.452	0.0
FHD	0.729	0.487	0.0	0.0
TSPDIV	0.655	0.592	0.0	0.0
SSPDIV	0.534	0.527	-0.361	0.0
TFHD	0.511	0.414	0.0	0.439
TOTRE	0.0	0.830	0.0	0.0
TSP	0.274	0.812	0.0	0.0
DEVELOPMENT INDEX (DI)	0.0	-0.568	0.362	-0.608
TOTSHR	0.0	0.500	0.335	0.409
TPCC	0.0	0.0	-0.408	0.0
SPCC	0.0	0.0	-0.422	0.0
GVOL	0.458	0.0	0.781	0.0
GFHD	0.0	0.0	0.759	0.0
SSP	0.298	0.492	0.664	0.0
RED-BACKED VOLE	0.0	0.0	-0.611	0.836
DEERMOUSE	0.0	0.0	0.0	0.0
WOODLAND JUMPING MOUSE	0.0	0.0	0.0	0.328
MASKED SHREW	0.0	0.335	0.0	0.0
SHORT-TAILED SHREW	0.0	0.0	0.0	0.0
EASTERN CHIPMUNK	0.0	0.0	0.0	0.0
MEADOW VOLE	0.0	0.0	0.0	0.0
RED SQUIRREL	0.0	0.0	0.313	0.0
VARIANCE EXPLAINED	5.568	4.388	3.399	3.225
ACCUMULATED PERCENT OF EXPLAINED VARIANCE	34.7	50.0	58.6	65.2

Note: The sorted, rotated factors are presented with readings less than 0.2500 replaced by 0.00.

Best-fitting prediction equations were calculated for the Capture Index for each species versus the DI in each habitat type (Table 9.2). Polynomial regressions were required to fit the peak numbers of short-tailed shrews, chipmunks, and red squirrels on mixed shorelines with moderate levels of cottage development. A similar peak was predicted with total captures on mixed shorelines, and species diversity on mixed and coniferous shorelines. The numbers of masked shrews decreased rapidly on deciduous and mixed shorelines with very little increase in the DI. Likewise the number of red-back voles decreased on coniferous shorelines and woodland jumping mice decreased on deciduous shorelines. Significant linear declines in number were observed for woodland jumping mice on coniferous shorelines for red-backed voles on mixed shorelines, and for deer mice in all three habitat types. There were no captures of woodland jumping mice on mixed shorelines with development greater than 0.0, and no prediction equation was estimated. Short-tailed shrews and chipmunks both showed a linear increase with development on deciduous shorelines. The stepwise multiple regression procedure was used to describe habitat selection (Table 9.3). A discriminant function analysis identified three groups of small mammal species. The variables required to make this separation were the DI and the percent conifer composition in the tree layer. The first cluster of species is located at high levels of coniferous composition and cottage development (Fig. 9.5). This group contains only red squirrels, and is significantly different ($P < 0.005$) from each of the other two clusters. A second cluster, including chipmunk, short-tailed shrew, and deer mouse shares the higher levels of development, but is found at lower levels of coniferous composition.

The main separation between the deer mouse and the chipmunk appears to be the level of development at which

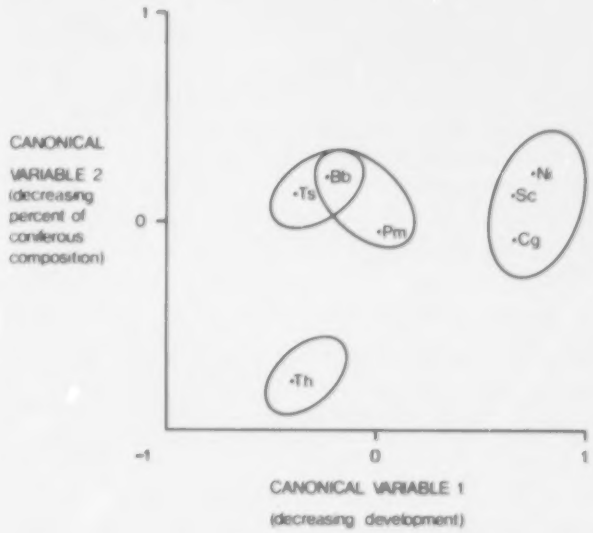

Figure 9.5 Separation of seven small mammal species on two canonical variables. The first variable is defined by the Development Index which describes a gradient of development. The second variable is the coniferous composition of the tree vegetations which describes a gradient of coniferous composition. Clusters of species that were not significantly separated by the analysis are circled.

Table 9.3 Best fitting prediction equations for animal captures versus the development index (DI)

Capture Index	Habitat	Equation	R value
All species (Small mammal density)	Coniferous	CI = 56.36 - 12.35 (DI)	R = 0.4544*
	Mixed	CI = 41.46 + 54.98 (DI) - 22.76 $(DI)^2$	R = 0.8236**
	Deciduous	CI = 39.09 - 0.763 (DI)	R = 0.0341
Small Mammal Species Diversity	Coniferous	D = 0.34321 + 1.04867 (DI) - 0.86527 $(DI)^2$ + 0.17463 $(DI)^3$	R = 0.7260**
	Mixed	D = 0.46551 + 0.26213 (DI) - 0.12816 $(DI)^2$	R = 0.6445**
	Deciduous	D = 0.437 - 0.019 (DI)	R = 0.1750
Masked Shrews	Coniferous	CI = 0.1391 (exp 0.3774 (DI)) -0.1335	No correlation available
	Mixed	CI = 0.1366 (exp -4.2239(DI)) -0.00029	
	Deciduous	CI = 1/ 0.59725 (exp 1.61079(DI)) -0.07745	
Short-tailed Shrews	Coniferous	CI = 2.01 - 0.358 (DI)	R = 0.1923
	Mixed	CI = 1.75 + 8.71 (DI) - 3.14 $(DI)^2$	R = 0.7663**
	Deciduous	CI = 1.04 + 0.652 (DI)	R = 0.4314*
Chipmunks	Coniferous	CI = 5.25 + 1.942 (DI)	R = 0.1741
	Mixed	CI = 4.016 + 86.55 (DI) - 54.729 $(DI)^2$ + 8.712 $(DI)^3$	R = 0.6501**
	Deciduous	CI = 4.2 + 5.13 (DI)	R = 0.4689*
Red Squirrels	Coniferous	CI = 2.1952 - 0.050 (DI)	R = 0.0147
	Mixed	CI = 0.1258 + 3.418 (DI) - 1.214 $(DI)^2$	R = 0.6221**
	Deciduous	CI = 0.1301 + 0.030 (DI)	R = 0.0907
Deer Mice	Coniferous	CI = 19.21 - 4.393 (DI)	R = 0.4620*
	Mixed	CI = 21.45 - 5.979 (DI)	R = 0.6503**
	Deciduous	CI = 23.96 - 4.352 (DI)	R = 0.2855
Red-back Voles	Coniferous	CI = CI 30.23 (exp - 3.3978(DI))	No correlation available
	Mixed	CI = 10.73 - 3.117 (DI)	R = 0.4411*
	Deciduous	CI = 4.05 - .954 (DI)	R = 0.2340
Woodland Jumping Mice	Coniferous	CI = 1.492 - 0.541 (DI)	R = 0.556*
	Mixed	No values observed at DI > 0	
	Deciduous	CI = 4.0 (exp - 1.848(DI))	

Note: *P < 0.05
**P > 0.01

peak populations are found, although the former was found to some extent on all plots.

The third group of species includes the masked shrew, woodland jumping mouse and red-back vole. This group, as a whole, is separated from the other two by the level of development at which it occurs. All species within this group were found at low levels of development, and were extirpated at extremely high levels of development in at least one habitat type.

9.5 DISCUSSION

The 56 study plots were small, allowing more replications in different habitat types at various levels of development but prohibiting the estimation of actual population size. Therefore, a CI was used as a measure of relative abundance.

9.5.1 VEGETATION

Cottage development directly affected vegetation through the planting and/or removal of species, and, indirectly, through the alteration of microhabitat and soil characteristics. Principal component analysis of the data identified three major axes of variability: vertical foliage distribution, level of development, and coniferous composition, or habitat type. Vertical foliage distribution varies with stage of succession and degree of development. The influence of succession was controlled, to a degree, by the selection of study plots, because very early stages were not investigated, and extremely mature shoreline areas were quite rare. The vertical foliage distribution, tree and shrub species diversity and other habitat variables are negatively correlated with development (Table 9.1).

Development also affects the habitat, as it introduces new species like mouse-ear chickweed *(Cerastium vulgatum)* and birdsfoot trefoil *(Lotus corniculatus)*. Many of these are classified as alien or as species naturalized from Europe (Fernald 1970). They alter the natural vegetation composition, and hence the food supply of granivores and herbivores in developed areas.

Each habitat type had a different initial vegetation composition, therefore the relationship between vegetation variables and development was dependent upon habitat classification. In many cases, a plant species was not found on a sufficient number of plots in a habitat type to establish a significant relationship. Therefore, the absence of a significant correlation does not necessarily mean that development does not affect that variable.

9.5.2 MASKED SHREW

The largest populations of masked shrew existed on undeveloped, deciduous shorelines (Fig. 9.4). A preference was shown for high shrub density, a primarily coniferous

shrub layer on deciduous shorelines and areas with abundant vegetation close to the ground (Table 9.3). This could satisfy the need for a moist microclimate (Quimby 1943; Manville 1949), which can result from the uneven tree age structure and the mature canopy found in habitat which is suitable for the masked shrew (Ozoga and Verme 1968).

The relationship between the masked shrew and its habitat has been considered by several authors (Brown 1967; Whitaker and Schmeltz 1973; Doucet and Bider 1974; Vickery and Bider 1978). Cottage development creates habitats similar to early successional stages as species composition and vegetation structure become altered. In a study of old field succession, Hirth (1959) found a distinct moisture gradient that ranged from dry in the pioneer stage to moist in the woodland shrub stage in the spring, summer, and fall months. Therefore, a preference for undisturbed habitat may represent the selection of a moist, stable microclimate associated with later stages of succession.

The most obvious evidence of a change in microclimate is the decrease in the number of moisture-loving plants like the starflower *(Trientalis borealis)* and the increase of such species as dandelions *(Taraxacum officinalis)* and hawkweeds *(Hieracium* spp.*)* with development on both deciduous and coniferous shorelines (Table 9.1).

On coniferous shorelines, the piling of brush, stumps, and logs and the opening of the closed canopy improved masked shrew habitat by providing shelter and foraging sites. However, on deciduous and mixed shorelines, the number of this species decreased with the clearing of the canopy and the creation of lawns.

The habitat preference of the masked shrew may change with ambient moisture conditions (Bole 1939). Regardless of summer moisture conditions, lakeshore habitat always provides a readily available water source.

Nesting areas and burrows may also be affected by development. Manville (1949) reported that the masked shrew may construct its own burrows in sphagnum moss *(Sphagnum* spp.*)* or loose soil. Nests are also found under logs, rocks, and brush. The reduction in the number of stumps and deadfalls and in the quality of the detritus layer, both caused by development reduces the suitability of an area as masked shrew habitat.

9.5.3 SHORT-TAILED SHREW

The short-tailed shrew is found in a wide range of habitat types (Burt 1940; Manville 1949; Hirth 1959; Ozoga and Verme 1968; Johnson et al. 1979). A preference is shown for areas with heavy herbaceous growth (Burt 1940; Morris 1979) and a moist environment (Getz 1961). However, moisture is not as important as it is for the masked shrew (Manville 1949). Morris (1979) found that the short-tailed shrew was associated with areas of high foliage density (between 0.25 and 1 m) with a deep mat of debris. Habitat selection appears to be dependent upon microclimate and microhabitat, both of which are affected by development, but it appears as if this species is affected less by development than the masked shrew. No significant linear correlation between population number and the DI was observed. These animals were most common at intermediate levels of development on mixed shorelines producing a nonlinear relationship with development (Fig. 9.3).

The multiple regression results show the short-tailed shrew has a definite preference for limited openings in the canopy in all habitat types. On deciduous shorelines, mints *(Labiatae)*, mallows *(Malvaceae)*, and hawkweeds *(Hieracium* spp.*)* (Table 9.3) were indicative of features which characterize good habitat such as the undeveloped edge of clearings. On mixed shorelines, the habitat was typified by variables responding to good light penetration and an established shrub layer. On coniferous shorelines, the preference was for areas with deciduous trees and ample ground coverage, the result of limited development in a predominantly coniferous area.

The mean nocturnal temperature affects activity patterns of the short-tailed shrew (Getz 1961). Diurnal temperature fluctuations and humidity are both affected, to some degree, by the density of shrubs and trees. Kirkland (1977) noted a decrease in the number of short-tailed shrews after the clear-cutting of both coniferous and deciduous forests, and suggested the decline reflected a change in soil moisture. Shrub and tree growth protect the soil from the drying effects of sun and cooling effects of wind and prevent convective heat loss at night. Kirkland (1977) also noted that short-tailed shrew populations increased with vegetation growth from 6 to 15 years of cutting. Short-tailed shrews tend to avoid mature stands in favour of mixed habitats with an uneven age structure. Maximum edge and interspersion of habitat types are produced along a segment of shoreline exhibiting evenly, well-spaced cottages.

9.5.4 EASTERN CHIPMUNK

The chipmunk exhibits an affinity for deciduous forest (Manville 1949; Kirkland and Griffin 1974; Dueser and Shugart 1978, 1979), and is noticeably absent in wetlands (Manville 1949) or conifer swamps (Ozoga and Verme 1968). The selection of deciduous shorelines by this animal was not indicated by our data. Peak populations were observed on mixed shorelines at medium levels of development. In the undeveloped state, the three habitat types had similar numbers of this species.

Burt (1940) noted that chipmunks were rarely seen at any distance from wooded or brush-covered areas, and Dueser and Shugart (1978, 1979) stress the importance of low shrub density with high shrub evergreen. The absence of a dense shrub layer produced good horizontal visibility which, according to Ryan and Larson (1976), is characteristic of desired habitat, particularly for perches.

Wooded areas are required for feeding (Ryan and Larson 1976), for shelter or dens (Burt 1940; Manville 1949). Dens were frequently found under cottages in the study area, and under or near piles of stones, and road embankments.

Burt (1940) noted that chipmunks were highly territorial in protected areas (about 50 m radius). One study plot (2500 m^2) on a highly developed lakeshore yielded, at least, eight individual chipmunks. Three other plots had more than four, indicating that developed lots are probably not protected portions of a territory although they may be a valuable portion of a home range. Developed areas may be important to chipmunks as supplementary feeding areas. Cottagers

frequently attract chipmunks directly by providing food and indirectly with bird feeders and unprotected garbage. This feeding may prevent the typical mid-summer lull in chipmunk activity (Ryan and Larson 1976), thereby increasing summer capture results.

9.5.5 RED SQUIRREL

Only 54 red squirrel captures were recorded during the course of this study. A large number of sprung, but empty, traps were found on plots with apparent large populations of red squirrels, indicating that traps may have been sprung in the initial stages of investigation. The number of captures may also have been reduced by the introduction of artificial food sources.

Under natural conditions, the red squirrel depends on mast production for summer and winter food (Klugh 1927; Kilham 1954; Kemp and Keith 1970; Rusch and Reeder 1978), and occupies a rigid territory that is determined by cone production in coniferous stands (Smith 1968; Kemp and Keith 1970).

The number of captures increased with the degree of coniferous composition, probably due to the corresponding cone production. The red squirrel was found to depend on high shrub density in deciduous habitat and on mature trees and large FHD values in coniferous habitat. At both low and high levels of coniferous composition, the CI increased with development. This was unexpected, due to the reduction in mast-producing trees and shrubs like beaked hazel nut *(Corylus cornuta)*, red oak, beech, white pine, and white spruce. However, many cottagers fed these animals during the months of July and August.

It was very difficult to determine if these red squirrel populations were permanent or transient. Kemp and Keith (1970) estimated juvenile to adult ratios to be 1.9:1 and 1.4:1 in the fall in two adjacent years of study. On our study plots the juvenile to adult ratio was 2.6:1 in August, which could indicate a transient population of individuals on developed plots. However, it is possible that the juvenile population is more easily captured on developed plots.

9.5.6 DEER MOUSE

The deer mouse was the most common small mammal species found in the study area, accounting for 41.8% of all captures. It was found in almost every habitat type. The ability of the deer mouse to occupy a broad niche confounds the impact of development with other environmental constraints.

This species requires a relatively permanent nesting site under roots or rocks (Sims and Buchner 1973), or in shelters that could include crevices beneath or among rocks, and cavities in trees (Manville 1949). The reduction of stumps, snags, and deadfalls that occurs with development in most habitat types restricts the availability of refuges and dens. Manville (1949) stresses the importance of retreats to this animal as an escape from predators.

Deer mice were found in all successional stages. On deciduous and mixed shorelines, this species was captured most frequently on mature undeveloped plots with a coniferous fringe and a large number of coniferous shrubs. On coniferous shorelines, a preference was shown for dense tree and shrub layers. Generally, good habitat for this animal provides dense shrub and tree layers with little herbaceous ground vegetation.

It is difficult to obtain accurate estimates of population size at any given time. Petticrew and Sadlier (1974) found greater differences in population size between years than between clear-cut and control areas. The length of the winter nonbreeding season has been considered a major determinant of population density in a given year (Petticrew and Sadlier 1974; Miller and Getz 1977). However, it is clearly evident from this study that deer mouse populations decreased with development in all three habitat types.

9.5.7 RED-BACKED VOLE

The red-backed vole was the third most common small mammal found on shorelines in the study area. Its number decreased with development, and increased with the level of coniferous composition. It normally selects a moist environment (Getz 1968; Miller and Getz 1977), particularly coniferous swamps (Manville 1949; Ozoga and Verme 1968). Since microclimate is not significantly different between low marshy areas and upland woody areas (Getz 1968), the selection of moist habitats can be attributed to the availability of free water (Miller and Getz 1977). Therefore, the clearing of vegetation exposes the surface of the ground, creating a drier, less stable microclimate.

The red-backed vole is found in areas with ample opportunity for escape (Ozoga and Verme 1968). Miller and Getz (1977) claim that diurnal raptors are its major predators. Therefore, shrub and ground cover are essential for protection. Krefting and Ahlgren (1974) attributed the increase in this species seven to 13 years after a fire to the associated increase in stumps, fallen trees, snags, logs and debris.

In all habitat types, the CI was associated with a high density of striped maple *(Acer pennsylvanicum)* and sugar maple shrubs which usually produce a very well-shaded forest floor. A particular preference was shown for diverse habitat in areas of low development. The abundance of vertical and horizontal cover appeared to be important.

This species has substantial water requirements which are reflected in its food preferences. Succulent soil fungi (Getz 1968) and the stalks and caps of mushrooms (Merritt and Merritt 1978) are valuable foods. Vickery (1969) added common, fleshy fruits like strawberries *(Fragaria* spp.*)*, the choke-cherry *(Prunus virginiana)*, the Canada mayflower *(Maianthemum canadense)*, the bunchberry *(Cornuscanadensis)*, hobblebush *(Viburnum alnifollium)*, and false Solomon's-seal *(Smilacina racemosa)* to the list. Canada mayflowers, bunchberries, hobblebush, wintergreen, and many seed-producing shrubs were observed to decrease with development in at least one habitat type (Table 9.1). Degradation of the detritus layer, which occurs with development, reduces the production of soil fungi and mushrooms, thereby affecting food supply.

9.5.8 WOODLAND JUMPING MOUSE

In many general studies of small mammals, the woodland jumping mouse has been captured infrequently. In this study, 48 captures were recorded, permitting limited analyses of habitat usage. The abundance of this species is related to the density of ground cover (Brower and Cade 1966), and the

quality of the herbaceous layer is important to its food supply as it consumes large quantities of fungus (Whitaker 1963), and the seeds and fruits of forest plants (Vickery 1979).

The edge effect caused by the shoreline increases the density of the ground and shrub vegetation as far back as 15 m from the water. This creates a favourable habitat for this species in undeveloped areas. However, as development increases, many food plants become scarce, and are replaced with unsuitable alternatives (Table 9.1).

The woodland jumping mouse prefers undeveloped, natural habitat with a well-developed shrub layer and particularly cool, moist areas. The Capture Index could be predicted by the density of shrub size, beech, sugar maple, striped maple and members of the genus *Viburnum*, indicating mature forests and good soils. Development tends to reduce the density of both ground and shrub vegetation, which results in a simplification of the edge effect. The woodland jumping mouse experienced an acute reduction in numbers with increasing development in all shoreline types (Fig. 9.3). On mixed plots, this animal was found only on lots with no development. The populations that were least susceptible to change were found on coniferous plots. This is probably due to the auxiliary food source provided by the seeds of coniferous trees.

9.5.9 SPECIES RELATIONSHIPS AND HABITAT CHANGE

Different small mammal species were found in a diversity of habitat types at various levels of development. The number of animal captures on each plot was modified by the undeveloped habitat which was adjacent to at least one side of it. This had a buffering effect on changes in numbers and activity, making the relative response of each species more important than actual population changes. It becomes desirable to classify each species by the habitat in which it lives. The general ecological distribution of small mammals on different shoreline types is illustrated in Figure 9.3. The red squirrel can tolerate high levels of development, but requires high levels of coniferous composition for the maintenance of its food supply. A high degree of development can also be tolerated by the chipmunk, short-tailed shrew and deer mouse. However, deer mouse populations were small at high levels of development. The red-backed vole, smoky shrew, and woodland jumping mouse are intolerant of development. The number of species captured, species diversity, and the total number of captures all reached maximum values in mixed habitats at moderate levels of development (Fig. 9.4). A second peak in total captures was observed at low levels of both coniferous composition and development. This peak was probably due, in part, to the

Table 9.4 Prediction equation of relative animal populations derived by stepwise regression on the vegetation variables.

Dependent Variable	Habitat Type	Prediction Equation	R^2	Standard Error of Prediction	Degrees of Freedom	F
Small Mammal Species Diversity	Deciduous	0.306 + 0.0005(SACERS) + 0.001(VIB) - 0.048(GOLDT) + 0.001(HAWK)	0.7956	0.0636	4/13	12.65
	Mixed	0.441 - 0.003(HAWK) - 0.021(BUN) + 0.411(AST) + 0.003(BETP) - 0.078(DAISY) - 0.003(STUMP)	0.9515	0.0523	6/12	39.22
	Coniferous	0.180 + 0.044(SPICEA) + 0.004(SPIR) + 0.003(SABIE) - 0.264(QUERC)	0.7171	0.0921	4/14	8.87
Capture Index for *Sorex cinerius*	Deciduous	- 0.216 + 0.119(SNAGS) + 0.695(PINUS) + 0.01(VIB) - 0.004(MYR) + 0.097(STJON) - 0.064(GOLDR) - 0.1(TSUGA) + 0.006(SABIE)	0.9928	0.1674	8/9	155.58
	Mixed	- 0.3 + 0.029(SABIE) - 0.764(ACERP) - 0.023(MYR) - 0.081(ABIE) + 0.04(GOLDT) - 0.001(VIB) + 0.017(CLIN)	0.9912	0.2157	7/11	176.81
	Coniferous	- 0.188 + 0.054(BETP) + 0.015(CLIN)	0.5989	0.2516	2/16	11.94
Capture Index for *Blarina brevicauda*	Deciduous	0.334 + 0.044(MINT) + 0.253(MAL) + 0.024(HAWK) + 0.038(STUMP) - 0.19(SPICEA) - 0.507(CUC) + 0.049(SPCC) - 0.003(LONIC) - 0.134(TSUGA)	0.9956	0.1703	9/8	200.19
	Mixed	10.306 + 0.044(SACERS) - 0.132(TOTSHR) -0.175(SSNAG) - 3.519(DI) + 0.761(POPUL) + 0.095(BETL) + 0.005(SPIR)	0.9932	0.4410	10/8	116.01
	Coniferous	3.191 + 0.619(DAISY) + 4.549(PYR) - 0.776(DI) + 0.702(CUC) + 0.018(SBETP) — 1.922(TSPDIV) - 0.015(VIB) - 0.052(SBETL) + 0.057(BETL)	0.9965	0.1635	9/9	283.46

Table 9.4 Prediction equation of relative animal populations derived by stepwise regression on the vegetation variables.

Dependent Variable	Habitat Type	Prediction Equation	R^2	Standard Error of Prediction	Degrees of Freedom	F
Capture Index for *Tamias striatus*	Deciduous	7.563 + 0.419(MINT) - 0.307(SPIR)	0.8821	4.6458	2/15	56.12
	Mixed	7.911 + 11.022(PYR) + 1.891(SAMB)	0.6926	9.1263	2/16	18.02
	Coniferous	10.584 + 3.486(DAISY) - 24.809(TSPDIV) + 0.283(THUJA) - (SSNAG) + 0.746(POPUL) + 0.889(BETL) -0.092(BUCK) + 0.091(LONIC) + 1.765(TSP)	0.9977	0.7891	9/9	436.79
Capture Index for *Tamiasciurus hudsonicus*	Deciduous	- 0.142 + 0.007(TAX) + 0.110(PYR) + 0.21(SPCC) - 0.199 (SAMB)	0.9137	0.1288	4/13	34.4
	Mixed	- 0.161 + 0.252(STILIA) + 0.310(PYR) + 0.22(POPUL) - 0.0311(STAR) + 0.021(SBETP) - 107(QUERC) - 0.002(SFAG) + 0.011(GOLDT) + 0.002(PEA)	0.9968	0.0894	9/9	313.71
	Coniferous	- 0.103 + 1.787(CUC) + 0.221(SNAGS) + 0.051(MYR) + 1.156 (BUN) - 0.009(STUMP) - .095(STAR) + 0.086(SBETL) + 0.02(LONIC) - 0.065(SPICEA)	0.9979	0.2336	9/9	471.14
Capture Index for *Peromyscus maniculatus*	Deciduous	− 5.775 + 0.25(SFAG) + 5.994(THUJA) + 0.651(SPCC) + 0.106(SBETP) + 1.314(STTON) + 0.025(SACERS) - 1.132(TSUGA) + 1.261(SNAGS) - .509(TILIA)	0.9929	2.1735	9/8	124.60
	Mixed	10.24 + 0.094(SFAG) - 0.55(SPICEA) + 0.094(SACERP) + 0.428(STILLA) - 0.968(PINUS) - 0.131(ABIE) - 7.372(CUC) + 0.094(STJON) + 0.482(SAMB)	0.9933	1.3192	9/9	148.92
	Coniferous	- 7.668 + 0.102(SACERP) + 2.113(TOTRE) - 3.56(BUN) - 0.091(STUMP) + 9.227(SSPDIV)	0.9317	3.0628	5/13	35.44
Capture Index for *Clethrionomys gapperi*	Deciduous	− 3.095 + 0.02(SACERS) + 1.435(PINUS) + 1.047(ACERP) + 0.810(DI) + 1.815(BUN) - 1.746(CUC) + 0.024(CREEP) + 0.013(PEA)	0.9985	0.2553	8/9	731.34
	Mixed	- 1.854 + 0.085(SACERP) + 0.314(SBETP) -- 0.308(STUMP) + 1.753(TOTRE) + 4.392(AST) + 0.933(POPUL) - 2.632(TSP) - 0.018(SABIE)	0.9927	1.0027	8/10	171.15
	Coniferous	- 3.306 + 13.098(BUN) + 0.092(SACERS) - 15.061(SLARIX) - 11.971(QUERC) + 0.586(ACERS) + 0.141(BUCK) - 0.458(SPICEA)	0.9981	0.9292	7/11	844.05
Capture Index for *Napeozapus insignis*	Deciduous	- 0.558 + 0.064(SFAG) + 0.003(SACERS) - 0.007(SACERP) + 0.59(TSP) - 0.075(TOTRE)	0.9966	0.1675	5/2	695.88
	Mixed	- 0.267 + 0.002(SACERP) + 0.005(SABIE) + 0.012(SFAG) + 0.007(MYR)	0.9183	0.5346	4/14	39.32
	Coniferous	- 0.055 + 0.012(SACERS) + 0.406(CUC) - 0.014(VIB) + 0.251(STJON) - 0.05(STAR) - 0.874(ACERP) + 0.026(MINT)	0.9855	0.1570	7/11	107.03

Note: The variables are listed in relative order of importance to the predictions.

large number of deer mice captured in that habitat type. Four of the seven species studied exhibited global or local peak numbers at moderate levels of development on mixed shorelines.

Development disrupts forest continuity with the removal of trees, shrubs, and ground vegetation, and the selective alteration of species composition. This, in turn, increases habitat heterogeneity, which is a good predictor of species

number (Morris 1979). Mixed shorelines exhibited maximum diversity of vegetation, and moderate levels of development provided good interspersion of developed and undeveloped habitats. M'Closkey (1976) states that shrub volume diversity might indicate habitat irregularity, which exerts a positive influence on rodent population diversity. Ozoga and Verme (1968) noted that immature stands of even age are not very productive for small mammals. The lack of diversity in such a case prevents the occurrence of large small mammal populations.

The effect of other aspects of cottage development, such as the creation of roads and service corridors, creates a different set of circumstances. These areas are not groomed like cottage lots. Therefore, a greater amount of shrub and herbaceous cover is created. Johnson et al. (1979) discovered that a corridor or service cut created a new habitat type with high species richness. They also found that species diversity values were almost identical in cut areas through conifer or hardwood, although the adjacent undisturbed habitats differ. Cottage development produces this new habitat type around all developed lakes, affecting small mammal numbers and distribution.

Development changes the species composition and numbers of the plant and small mammal community in shoreline areas. Similar changes are expected to occur in the avian, insect and reptilian communities. Johnson et al. (1979) stated that an assessment of the effect of powerline corridors on biotic diversity cannot be made on the basis of trends in a single group of organisms. This is also true for cottage development, inasmuch as the impact of development on small animals is but a portion of the impact on the total biotic community. Therefore, the effective use of these findings as a tool in environmental impact assessment is dependent upon similar information obtained for other groups of species.

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10. DEER HABITAT QUALITY AND INFLUENCES OF COTTAGE DEVELOPMENT IN CENTRAL ONTARIO

E. ARMSTRONG, D. EULER and G. RACEY

10.1 SUMMARY

Much of central Ontario's white-tailed deer *(Odocoileus virginianus)* range is also a prime recreational area, particularly around lakes where cottage development frequently takes place. Winter habitat used by deer during the winters of 1978 and 1979 was divided into 4 functional types: travel lanes, night bedding areas, day bedding areas, and feeding sites. These functional habitat types were separated on the basis of canopy closure, coniferous and deciduous browse units, vegetation volume, and number of dead branches. When cottages are built in these areas the quality of winter habitat is reduced. These findings provide a simple model of deer habitat quality, and a basis for minimizing the impact of cottage development on winter habitat.

10.2 INTRODUCTION

White-tailed deer in central Ontario have recently experienced drastic population declines (King 1976; Ontario 1978). This region is also experiencing an increased demand for lakeshore cottage development and recreational activity. Many of the remaining winter concentration areas used by deer include large sections of predominantly coniferous lake shoreline. These areas are important components of winter range and include both travel lanes and shelter areas. Lakeshore cottage development can affect shoreline vegetation through the removal of trees, and installation of power lines and roads and can reduce the quality of these areas for deer.

Several different methods have been proposed to quantify deer wintering areas. Early analyses were based on the proximity of food and cover (Webb 1940) and on general forest cover type (Christensen 1962). Huot (1974) differentiated feeding sites from bedding areas. Telfer (1967) recognized 3 subsections within a yard (feeding, feeding/shelter, and shelter). Stocker and Gilbert (1977) determined the ability of various winter habitats to provide protection from deep snow, wind and low temperatures, to offer areas of night and day bedding, feeding, and escape cover, and to allow mobility. A high volume of overhead vegetation may also be a component of optimum winter shelter (Telfer 1978). The objectives of this study were to measure key habitat parameters in terms of their usefulness to deer, and to determine the ways in which cottage development affects these parameters. The results should provide a practical basis on which planning decisions can be made to minimize any negative impacts of cottage development on the quality of deer winter habitat.

10.3 STUDY AREA

Field work was concentrated in 2 areas in central Ontario, one on the south shore of Lake Muskoka in the Regional Municipality of Muskoka (45° 02'N, 79°30'W)., the other between Percy and Haliburton Lakes in the County of Haliburton (45° 13'N, 79° 22'W). Forest type, topography, and shoreline usage by deer are similar in the 2 areas. Eastern hemlock *(Tsuga canadensis)*, white pine *(Pinus strobus)* and eastern white cedar *(Thuja occidentalis)* are the most abundant coniferous trees, while sugar maple *(Acer saccharum)*, yellow birch *(Betula alleghaniensis)*, and red oak *(Quercus rubra)* are common deciduous trees. The conifers are concentrated along ridges and north and west-facing lakeshores, while deciduous trees predominate on upland slopes and south and east-facing shorlines.

Both study areas are bounded on their east and west borders by lakeshore, and at least 1 prominent conifer-dominated ridge bisects each area. Small conifer-lined lakes and swamps are situated in the interior of each region. Road networks and developed shorelines are present in both areas, although the Lake Muskoka region contains a greater length of shoreline and is proportionately more developed.

10.4 MATERIALS AND METHODS

Winter field work was conducted between 27 January and 10 March 1978 and between 8 January and 9 March 1979. Four components of winter deer habitat were identified as night bedding sites, day bedding sites, travel lanes and feeding areas. Night bedding sites used during a night of relatively severe winter conditions (minimum night temperature at least −10°C), were located by back-tracking from fresh tracks and verified by observing snow accumulation and characteristics. Day bedding sites used during sunny, relatively mild days in mid to late winter were identified in a similar way. Travel lanes were defined as areas where deer maintained a distinct trail throughout the winter regardless of snowfall. Major feeding areas were identified by field observations of browsed plants. Night bedding and travel lane areas located near the shoreline were classified as sheltered shoreline areas. Coniferous shorelines where cottages had been built were kept in a separate category (cottaged coniferous shorelines) and compared to sheltered shoreline areas.

Habitat measurements were made of all habitat classifications during early May of 1978 and 1979 before leaf-out and after the snow had melted. Circles with a radius of 4.0 m and an area of 0.005 ha were positioned to contain 2 or more night beds, 1 or more day beds, 1 feeding site, section of a travel lane, or portion of a cottage lot. On cottaged coniferous areas circles were selected randomly. Where 1 circle met the criteria for more than 1 functional habitat type, the data were jointly recorded. Habitat measurement techniques were modified from those first initiated by James (1971).

Table 10.1 Summary statistics (mean ± SD) for functional habitat types in central Ontario deer concentration areas.

Variable	Night (n=52)		Day (n=25)		Feeding (n=22)		Travel (n=28)	
Slope %	18	±11	10	±7.0	14	±6	26	16
Position*	4.2	±1.5	4.6	±1.8	3.5	±1.3	4.7	±1.4
Canopy Height (m)	16	±4	12	±8	17	±6	19	±4
No. Dead Branches below 2m	28	±25	7	±12	13	±19	9	±11
Vegetation Volume (%)	50	±20	6	±8	17	±17	36	±22
No. Large Trees (24 cm dbh)	1.8	±1.4	0.7	±0.9	0.6	±0.9	1.8	±1.2
No. Small Trees (8-24 cm dbh)	5.5	±3.9	3.2	±2.9	3.0	±2.0	3.1	±3.4
Tree coniferous Composition (%)	65	±27.2	7	±23.0	19	±24	69	±30.0
No. Coniferous Shrubs	2.5	±3.9	4.3	±14.1	13.9	±17.8	3.5	±7.2
No. Deciduous Shrubs	4.3	±9.1	14.4	±14.0	20.7	±27.4	3.8	±5.5
No. Coniferous Browse Units*	847	±403	100	±280	3831	±4010	471	±1893
No. Deciduous Browse Units**	432	±1414	429	±530	2176	±2908	466	±1088
Estimated canopy closure (%)	73	±18	9	±20	22	±19	70	±23
Sum of Density Board "Edge" (no. shrubs x canopy height)	8.3	±2.9	6.8	±4.0	9.0	±2.7	6.6	±3.0
Ground Coverage	1.4	±2.0	1.4	±2.4	6.0	±5.1	2.0	±3.0
Shrub Coverage	12.8	±3.4	3.0	3.3	6.3	±4.7	11.2	±4.9
Tree Coverage	11.9	±3.8	2.9	±4.2	4.5	±4.2	11.0	±4.4

*from 1 on level ground below slope to 6 on plateau above
**Passmore and Hepburn (1955)

Sampling was accomplished at 3 levels, the full circle (position and tree characteristics), two perpendicular rectangles 1.5 m wide and 8 m long (shrubs, browse units, dead branches and density board) and four 1-m^2 quadrats, 1 m from the circle centre (volumes and coverage). The variables measured are listed in Table 10.1. The presence of branches in each of 6 equal board segments on a 2.0 density (Nudds 1977) was scored at +1, and a density board score was calculated by totalling these measures for both rectangles. Foliage cover and volume estimates were recorded for the ground (0.1-1.5 m), shrub (1.5-9.0 m), and tree (>9.0 m) layers as measured at the four subquadrats using a technique modified from Willson (1974). These subquadrats formed the base of a three-dimensional column which extended to the top of the canopy. The estimated percentage of volume occupied by vegetation in each layer was averaged for the four subquadrats. These values were summed for the layers to produce a measurement of total vegetation volume. The presence or absence of vegetation at each corner of the column was also noted and totalled by layer, giving a maximum score of 16 per circle.

The data for all 4 functional habitat types were subjected to Principal Component (PCA) and Discriminant Function Analyses (DFA). The PCA rearranged the variables into a set of independent groups of variables called components which define, in decreasing order of importance (variance explained), the major structural features of the winter deer habitat. The stepwise DFA selected those variables which best discriminated among the four functional habitat types and provided an F-matrix to test significance. This subset of variables which provided maximum discrimination was used in the calculation of two canonical variables on which the observations and the group mean were plotted.

DFA was also used to compare sheltered shoreline areas to cottaged coniferous areas to determine those habitat variables which best differentiated the two areas.

10.5 RESULTS

The summary statistics for the 4 functional habitat types are presented in Table 10.1.

The 1st principal component of the PCA is most highly correlated with tree cover, canopy closure, vegetation volume, percent conifer composition, and shrub coverage, all of which relate to the degree of overhead cover (Table 10.2).

Table 10.2 Results of the Principal Component Analysis (PCA) of habitat variables in central Ontario deer concentration areas (only 5 most important components listed)

Variable	I (28.2)*	II (45.1)	III (57.4)	IV (67.5)	V (73.6)
Canopy Closure	0.899	0.0	0.0	0.0	0.0
Tree Coverage	0.899	0.0	0.0	0.0	0.0
Vegetation Volume	0.847	0.0	0.0	0.0	0.0
Coniferous Composition	0.809	0.0	0.0	0.0	0.0
Shrub Coverage	0.772	0.0	0.0	0.347	0.0
Canopy Height	0.512	0.361	0.0	−0.442	0.0
No. Deciduous Browse Units	0.0	0.908	0.0	0.0	0.0
No. Deciduous Shrubs	0.0	0.908	0.0	0.0	0.0
"Edge"	0.0	0.830	0.446	0.0	0.0
No. Coniferous Browse Units	0.0	0.0	0.902	0.0	0.0
Ground Coverage	0.0	0.0	0.899	0.0	0.0
No. Coniferous shrubs	0.0	0.0	0.858	0.0	0.0
Sum of Density Board	0.0	0.262	0.0	0.703	0.0
No. Small Trees	0.0	0.0	0.0	0.681	0.0
No. Dead Branches	0.349	0.0	0.637	−0.637	−0.281
Position	0.0	−0.282	0.0	0.0	0.771
Slope	0.0	0.0	0.0	0.574	0.574
No. Large Trees	0.422	0.0	0.0	−0.497	−0.272

*Cumulative proportion of variance explained

The number of deciduous shrubs and browse units and the 'edge' measure are highly correlated with the 2nd component reflecting its relationship to the deciduous understory. The 3rd component is most highly correlated with the number of coniferous browse units and shrubs, and the ground cover, all of which represent the coniferous understory. The 4th component defines the structural characteristics of the understory layer being most highly correlated with the density board score and the number of dead branches and small trees. Topographic features of the area (i.e. slope and position) reflect the 5th component. The first 5 principal components account for 73.6% of the variability in the data set.

Table 10.3 Results of the Discriminant Function Analysis (DFA) for Functional Habitat types in central Ontario deer concentration areas (87% of the cases classified correctly).

Habitat Variable Selected by DFA	Coefficients for the first canonical variable	Coefficients for the second canonical variable
Percent Canopy Closure	0.03676	0.01855
Coniferous Browse Units	−0.00017	0.00045
Deciduous Browse Units	−0.00014	0.00040
Percent Vegetation Volume	0.02080	−0.00778
No. Dead Branches	−0.00068	0.01695
Constant	−2.26548	−1.69748

Five variables each highly correlated with a canonical variable, were selected by the DFA to isolate the 4 functional habitat types. These variables were: canopy closure, coniferous browse units, deciduous browse units, vegetation volume and number of dead branches (Table 10.3). Maximum differentation among the habitat types was based on variables similar to those selected in the PCA of all habitat types combined with 2 variables appearing from the 1st component (canopy closure and vegetation volume) as well as 1 of the most important variables from each of components 2, 3, and 4. The relationship among the habitat types is apparent in a diagrammatic representation according to 2 canonical variables constructed from the DFA (Fig. 10.1). Travel lanes are almost entirely contained within the sphere of values represented by night beds. Night bedding areas and feeding sites occurred over a relatively wide range of habitat conditions, while day bedding habitats were less variable. Feeding areas overlapped slightly with, and were adjacent to, all other habitat types. Day bedding areas extended primarily over feeding sites, although they were peripheral to night bedding areas and travel lanes.

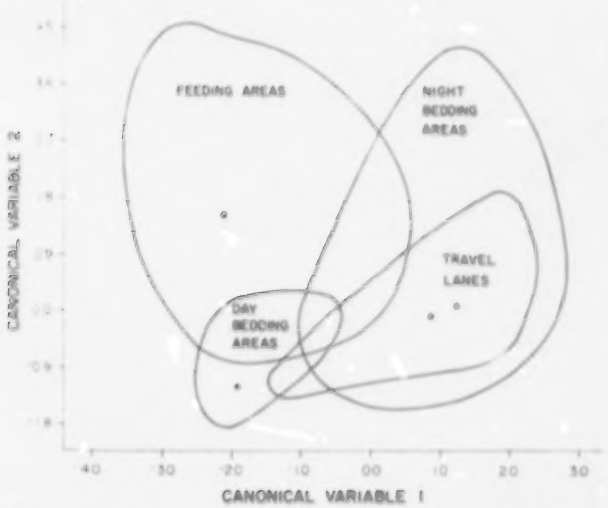

Figure 10.1 A 2-dimensional ordination of the functional habitat types of deer concentration areas based on the DFA. Solid circles indicate mean; lines delimit range of values.

Table 10.4 Summary Statistics (Mean ± SD) for sheltered shoreline areas and cottaged coniferous areas in central Ontario deer concentrated areas.

Variable[a]	Cottaged Coniferous (N = 36)	Sheltered Shoreline (N=20)
Slope	18 ± 15	27 ± 14
Position	3.5 ± 1.4	4.1 ± 1.6
Canopy Height (m)	16 ± 17	18 ± 4.4
No. Dead Branches	4.8 ± 13.8	11.7 ± 10.3
Vegetation Volume (%)	21 ± 19	30 ± 17
No. Large Trees	1.1 ± 1.3	1.3 ± 1.2
No. Small Trees	2.2 ± 2.8	6.1 ± 4.4
Coniferous Composition (%)	53 ± 44	75 ± 23
No. Coniferous Shrubs	2.8 ± 3.0	1.5 ± 2.8
No. Deciduous Shrubs	5.5 ± 10.9	1.4 ± 2.2
No. Coniferous Browse Units	35 ±125	94 ±365
No. Deciduous Browse Units	121 ±369	143 ±410
Canopy Closure	48 ± 35	79 ± 16
Sum of Density Board	2.9 ± 3.0	7.2 ± 3.2
"Edge" (m)	143 ±190	51 ± 57
Ground Coverage	1.1 ± 2.0	0.9 ± 1.9
Shrub Coverage	4.7 ± 4.8	12.4 ± 4.1
Tree Coverage	8.3 ± 5.6	12.5 ± 3.3

[a]see text and Table 1 for discussion of units.

Summary statistics for sheltered shoreline and cottaged coniferous areas are presented in Table 10.4. The DFA indicated that the 3 habitat variables that most clearly differentiate cottaged areas from sheltered shoreline areas were shrub coverage, density board score and the "edge" measure (Table 10.4). These 2 areas are well-separated according to the discriminant function, although some overlapping does occur (Fig. 10.2).

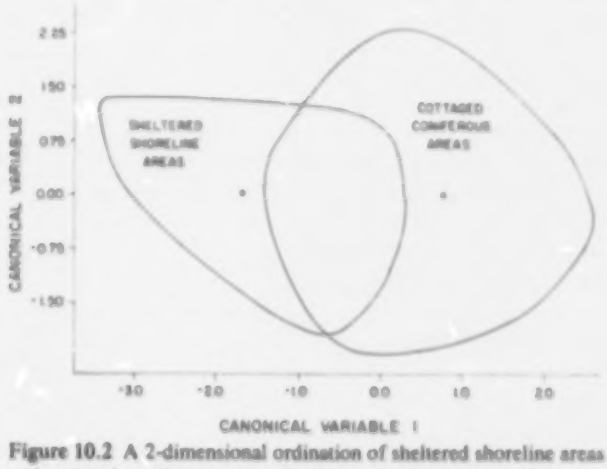

Figure 10.2 A 2-dimensional ordination of sheltered shoreline areas and cottaged coniferous areas of a deer concentration area based on the discriminant function analysis. Solid circles indicate mean; lines delimit range of values.

10.6 DISCUSSION

There is a high degree of diversity in habitat structure and composition in winter concentration areas in central Ontario. The major structural features of the habitat correspond to overhead cover and vegetation volume, the deciduous and coniferous understories, and their vertical and horizontal structure. These variations can be attributed to differences in coniferous composition, topography and aspect. In deer concentration areas, this habitat diversity is necessary to provide all winter requirements of deer.

The classification of winter deer habitat by functional type seemed valid in this regard, as travel lanes, night and day bedding sites and feeding areas occupied statistically different positions within the discriminant function ordination. This ordination is compatible with that developed by Huot (1974) in Quebec to differentiate shelter from feeding areas based on the food available (number of stems/acre) and the overhead shelter (volume of coniferous stems).

The importance of shelter to wintering deer has been illustrated over a wide geographical range and habitat types (Huot 1974; Wetzel et al. 1975; Drolet 1976; Kearney and Gilbert 1976). In this study, night bedding areas and travel lanes had high values for canopy closure and vegetation volume, although the former tended to be slightly more dense. A thick, high canopy can reduce snowfall and increase the moisture content, allowing firm trails to be formed (Verme 1966; Ozoga 1968). Mature, coniferous stands also have reduced wind flow, a narrow thermal spread, and a relatively stable microclimate. The fact that vegetation volume also appeared in the DFA suggested that the vertical depth and amount of overhead vegetation were important. Telfer (1978) suggested that vegetation volume and high canopy closure would reduce snow accumulation and wind speed.

According to the 1st discriminant function axis, travel lanes were found within the range of values represented by night beds. Many factors are involved in the location of travel lanes, including overhead and horizontal cover, ease of maintenance, and accessibility to other required habitats. Discriminant function scores for night bedding areas and travel lanes were adjacent to, and overlapped slightly with, those for feeding areas. This paralleled the field situation in which some feeding sites are part of, or adjacent to, shelter areas while others were farther away. This quantitative analysis concurred with previous descriptive reports. Wetzel et al. (1975) reported that most browsing took place within 40 m of shelter, and Dorn (1970) found that it was dependent upon and occurred near bedding sites. Huot (1974) observed that deer forage in small brushy openings adjacent to dense coniferous areas.

Day bedding sites also appeared to be important components of deer concentration areas. They had the lowest values for canopy closure and vegetation volume and were not chosen for their feeding potential as they had the lowest values for coniferous and deciduous browse units. Deer maximized solar insolation by bedding down in areas with low overhead cover on sunny days. Other qualitative reports have indicated that deer use exposed sites on sunny days (Verme 1966). The availability of suitable day bedding sites may be most critical on mild days in late winter when deer are stressed by severe weather, depleted browse, and fetal development. Severe winter conditions can reduce the rate of fawn survival in spring (Kuceva 1976; Verme 1978).

The major habitat differences among these 4 functional habitat types (Table 10.3) can be combined with the summary statistics (Table 10.1) to evaluate the potential of any given area to support deer (Fig. 10.3). Candidate habitat areas can be rated against the mean values for those 5 variables selected in the DFA to determine their relative value as night bedding areas, day bedding areas, travel lanes and feeding areas. This "modelling" does not necessarily predict deer usage, but rather the habitat value of any given area to deer. Other factors, e.g. predation, often affect use of any given habitat.

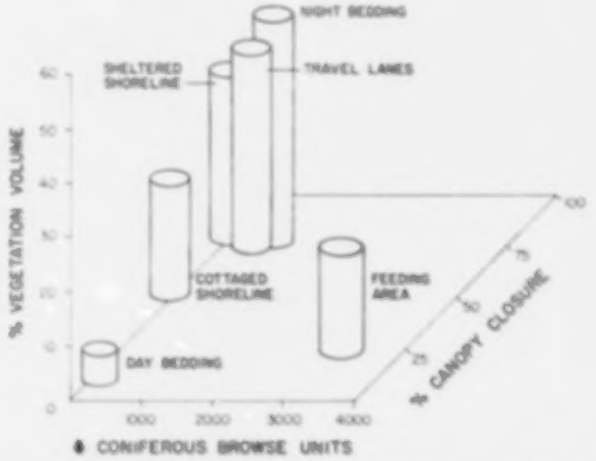

Figure 10.3 A diagrammatic representation of the relationships of deer habitat components and developed shoreline areas according to the means of the 3 habitat variables selected by the discriminant function analysis. Cottaged shoreline is the same as cottaged coniferous areas referred to in Table 4 and 5 and Fig. 2.

Significant habitat differences were found cottaged between coniferous shorelines and sheltered shorelines area. Cottaged areas had reduced shrub cover, coniferous composition, and branch distribution as a result of tree removal and pruning by cottagers. In some locations, coniferous trees, particularly small ones, were removed by cottagers to favour deciduous trees like white birch (*Betula*

Table 10.5 Results of the discriminant function analysis (DFA) for sheltered shoreline and cottaged coniferous areas in central Ontario deer concentration areas. Approximately 66% of the cases were classified correctly.

Habitat Variable Selected by DFA	Coefficients for the first canonical variable	Coefficients for the second canonical variable
Shrub Coverage	−0.12875	−0.17373
Sum of Density Board	−0.26200	0.26494
"Edge"	0.00373	−0.00234
Constant	1.71702	0.34666

papyrifera). Cottaged shorelines had higher "edge" values than sheltered shoreline areas, probably the result of increased shrub production after the canopy had been opened (Behrend and Patric 1969). Deer were not observed to respond to this increase in available browse by modifying their travel patterns or feeding more often along the shoreline.

The net result of ribbon shoreline development is to fragment the continuity of the coniferous fringe, thereby reducing its value as travel lane and night bedding habitat. Some increase in browse can be expected although the value of increased food may not outweigh the loss of shelter. Several separate components of deer winter habitat are important and must be managed accordingly.

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11. REPTILE AND AMPHIBIAN HABITAT AND HUMAN ACTIVITY IN CENTRAL ONTARIO

K. CLARK and D. EULER

11.1 SUMMARY

The objective of this study was to assess the impacts of habitat disturbance caused by cottage development and acid precipitation on selected amphibian and reptile populations in central Ontario. Spotted salamander egg masses, spring peeper calling sites, and painted and snapping turtles' egg-laying sites were censused in the Muskoka and Haliburton districts of central Ontario along 25 km of developed and 25 km of undeveloped shoreline. Habitat measurements were taken within 1 m radius circles centred on areas which were used for breeding and on areas which appeared to be suitable habitat but which were not used. A development index was also used to assess the effect of habitat disturbance on the breeding habitat. pH was measured throughout the breeding season at spotted salamander egg-laying sites and spring peeper calling sites.

Spotted salamander egg masses were found in highly developed, deciduous open habitats which were mainly ditches along cottage roads. These ditches were associated with high pH probably because of buffering from the $CaCO_3$ in sand and gravel used on the roads. The importance of pH as a factor influencing hatching success may limit the results of habitat analysis to areas which are being acidified.

Spring peepers were associated with large marsh habitats with extensive ground cover, few trees and little habitat disturbance. Spring peeper density was also positively correlated with pH indicating acidic precipitation may be negatively affecting spring peeper populations.

Turtle egg-laying sites were associated with open habitats with exposed earth, bare rock and reduced habitat disturbance. Turtle habitat is negatively affected by habitat disturbance and it is likely that human activity will also be negatively influencing turtle populations.

11.2 INTRODUCTION

Encroachment of human activities into undisturbed habitats has led to increasing concern about changes in wildlife populations in these areas. Investigations into the effects of habitat alteration have concentrated mainly on avian populations and game mammals such as moose and deer (e.g. Emlen 1974; Webb et al. 1977; Possardt and Dodge 1978). Reptiles and amphibians are usually not included as wildlife species and there is seldom concern for their fate when wildlife impact assessments are made for a development proposal. The limited available information indicates that habitat disturbance causes deleterious effects on reptile and amphibian populations. For example, Orser and Shure (1972) have shown that disturbance of drainage patterns by urbanization causes instability within stream habitats due to increased scouring and erosion of stream bank soils and the loss of protective vegetation cover. This instability has reduced or eliminated the dusky salamander *(Desmognathus fuscus fuscus)* from many disturbed areas. In Britain, Beebee (1979) found that the population sizes of five species of amphibians were reduced near intensively developed town areas.

Not only are reptile and amphibian populations in jeopardy because of habitat disturbance, but there is also the threat of a qualititative degradation of habitats in areas with soils having a low buffering capacity which receive acid precipitation. The eggs of several species of frogs and salamanders have been shown to exhibit reduced hatching success in acidic waters (Gosner and Black 1957; Cooke and Fraser 1976; Pough 1976; Pough and Wilson 1977).

The loss or reduction of reptile and amphibian populations could have far-reaching effects in both terrestrial and aquatic ecosystems. Salamanders are one of the top carnivores in small stream ecosystems and their removal could lead to serious alteration of trophic relationships (Orser and Shure 1972). Burton and Likens (1975a) have suggested that salamanders' primary role in forest ecosystems is as a high protein food source for predators since they are potentially a better source of energy than either birds or small mammals. Salamanders are also important in regulating invertebrate populations. Burton and Likens (1975b) have estimated that adult amphibian biomass is equal to or higher than either birds or small mammals. This is strong evidence that amphibians make a significant contribution to the food chain.

Reptiles and amphibians in central Ontario are subject to both increasing habitat disturbances and increasing acidification of breeding habitat in rivers, ponds, streams and lakes. In the last 25 years many aquatic areas have been bordered with cottages, roads and transmission line corridors with maximum disturbance within 50 m of shore. This area usually coincides with the highest densities of reptiles and amphibians because of their association with a moisture gradient (Roberts and Lewin 1979). Most of the ponds and lakes in central Ontario on the Canadian Shield have soils with a low buffering capacity for the highly acidic precipitation (mean annual pH = 4.1) falling in this area (Dillon et al. 1978).

The objectives of this study were: to determine the characteristics of the breeding habitat of three amphibian and two reptile species to measure the effects of habitat disturbance on these species' breeding habitat, and to establish, where possible, any effects of acidification on their population sizes.

11.3 METHODS

The study was conducted in the Muskoka and Haliburton districts in central Ontario. Nine lakes were selected with a total of 25 km of cottaged and 25 km of uncottaged shoreline. The lakes were chosen to represent a range of shoreline and littoral zone substrates and vegetation, and water quality of lakes in the area.

Five species were selected as representatives of herptiles using the shoreline and littoral zone habitats disturbed by cottage development. The species were censused in their breeding habitats since this is where habitat requirements are usually restricted. Censusing in the breeding habitat also best allows predictions regarding the relationship between the occurrence of an individual and its characteristic vegetational requirements.

The spring peeper *(Hyla crucifer)* was censused between 1800 and 2400 h except on evenings when the temperature dropped below 0°C or if there was a heavy rain. All areas within 50 m of the shoreline were censused for calling males. On developed lakes where a road circumferenced the lake, the road was traversed at a constant speed with frequent stops to listen for calling males. On undeveloped lakes, a canoe was used to inspect the shoreline. Calling males were located where possible and recorded on a large scale lake map. Where a high density of calling males made this impossible, the area was delineated and the number of males estimated. Each lake was censused at least three times between 1 May and 15 June 1979.

Egg-laying sites of the spotted salamander *(Ambystoma maculatum)* were censused from 25 April to 15 June 1979. Shoreline and backshore ponds within 50 m of shore were searched and all egg masses were counted and the location flagged.

Snapping turtle *(Chelydra serpentina)* and eastern painted turtle *(Chrysemys picta picta)* egg-laying sites were censused throughout June and July along the shore within 50 m of the lake. In most cases the digging of the snapping and painted turtles could be distinguised by tracks in the soil. There were several areas, however, where there had been considerable digging and where predators, particularly raccoons *(Procyon lotor)*, had caused such a disturbance that it was not possible to identify the diggings of each species. To avoid having to dig up areas to positively identify the diggings of each species and find the exact locations of eggs, only sites where turtle diggings had occurred were used as indication that some eggs had been laid. Areas where turtles had dug, but the soil was too shallow to bury the eggs, were not included.

Vegetation measurements were taken within a 1-m radius circle (3.14-m^2 area) centered on the calling male site or egg mass or turtle digging sites. All measurements were taken after the trees had leafed out. The vegetation variables are listed in Table 11.1. All volume measures were taken from the centre of the circle and the volume occupied by either foliage or deadwood within the layer was estimated. Vegetation cover was an estimate of the percent vegetation cover of an orthogonal projection passing down through each respective layer. Conifer composition was estimated as the percentage of coniferous foliage in a 10-m radius in either the shrub or tree layer. The submerged layer was the volume below water, the ground layer was 0 – 1.0 m, the shrub layer was 1.1 – 9.0 m, and tree layer was 9.1 m and over.

An index of habitat disturbance was also measured in each circle. This index, the ground disturbance index (GDI), was the percent of the area in the ground layer in the 1 m radius circle disturbed by human activities. An area was operationally defined as disturbed if the natural vegetation had been altered or removed, a man-made object was present or if natural succession had been arrested or returned to an earlier stage. These are referred to as ground development index (GDI), shrub disturbance index (SDI) and tree disturbance index (TDI) (Racey and Euler 1981).

Habitat measurements were made in the 1 m radius circles area wherever spotted salamander egg masses were found on developed and undeveloped lakes.

For spring peepers, habitat measurements were taken from a random sample within the areas where males were heard calling for each of two kinds of sites. One was where more than one male was heard calling within a 1-m circle during at least two censuses. The other was where a single male was heard calling during at least two censuses or where 2 males were heard calling at least once. These two samples were taken to represent a high and low level of breeding habitat quality, respectively. An equal sample of approximately 50 for each kind of site was taken on a random basis from the calling sites on developed and undeveloped lakes.

For turtle egg-laying sites, circles were centred in areas where considerable digging had occurred. Some of these nests had been preyed upon. Approximately 50 random samples for each species were taken at these sites on developed and undeveloped lakes.

Habitat measurements were also taken in areas where each species was not found but which appeared to be potentially suitable breeding habitat. These areas were delineated using different criteria for each species. The criteria used were those which described the basic habitat requirements for the breeding site. Spotted salamander habitat was all backshore standing water. For spring peepers, all areas with some emergent vegetation and 2-m backshore were included. Painted and snapping turtles' egg-laying sites were dry areas where there was less than 50 percent tree cover and less than 75 percent shrub cover. A sample of circles randomly located within these areas was measured. An equal sample was taken for developed and undeveloped lakes. These habitat circles allowed a comparison between what each species was and was not using for breeding.

Two different approaches were taken in establishing the habitat associations and the effects of habitat alterations on the herptile species. For the spotted salamander, accurate counts of the number of egg masses were made within each 1-m radius circle. Higher densities of egg masses were assumed to be an indicator of better quality habitat (Strijbosch 1979). Regression analyses using the number of egg masses as the dependent variable and the habitat characteristics as

independent variables allowed the establishment of a graded scale of habitat quality (as reflected by the density of egg masses) with both the habitat characteristics and varying levels of habitat disturbance. BMDPR7 computer programs were used for the analysis (Dixon 1975).

The methods of Conner and Adkisson (1976) were employed to establish the habitat characteristics of spring peeper and painted and snapping turtle breeding sites. This method uses a stepwise discriminant function analysis (Dixon 1975) to select the most important variables in distinguishing between the group habitats. For spring peepers a three group DFA was used with sites where one, more than one, and where no males were heard calling. This allowed determination of a gradient of quality of the habitat for spring peeper breeding. For turtle egg laying sites a two group DFA was used with sites where digging occurred and did not occur. After the habitat variables were selected, the DFA then used a canonical correlation technique to calculate a vector in n-dimensional space (n = the number of habitat variables selected). The importance of each habitat variable in distinguishing between the groups is dependent on the absolute value of the corresponding coefficient. A mean score can be computed for each group to establish its position along each discriminant function axis. Each score is computed by multiplying the mean of each habitat variable for that group by the appropriate coefficient and summing these values. To determine whether a particular area is suitable breeding habitat for a species, the value of the habitat characteristics measured in that area are used in the discriminant function equation to compute a score. The position of this score along the discriminant function axis will indicate whether the habitat is potential breeding habitat or not suitable breeding habitat. Conner and Adkisson (1976) have suggested that the mid-point between the mean score for sites used and those not used be the cutoff point in classifying between the groups. This linear decision scale classifies habitats as potentially usable or non-usable.

By incorporating the ground development index (GDI) as one of the habitat characteristics in the DFA, it was determined whether development was important in characterizing amphibian or reptile breeding habitat. If the development index was selected by the stepwise DFA, the habitat variables which were associated with GDI were described using linear regression (Dixon 1975).

The major assumption behind both the linear regression analysis and the DFA is that a predictable relationship exists between the occurrence of an organism and its characteristic vegetational requirements. There is strong support for this assumption in other organisms, particularly birds (MacArthur and MacArthur 1961; Wiens 1969; James 1971). For amphibians, habitat characteristics have been shown to be an important parameter in green frog territory quality and they are reflected in the breeding success (Wells 1977). Strijbosch (1970) has shown that the occurrence of six species of amphibians is related to the plant communities and physical/chemical habitat characteristics.

pH measurements were taken to establish whether spotted salamander and spring peeper habitats were acidic and if so to determine whether acidity was influencing the quality of breeding habitat.

pH measurements were taken at all spotted salamander ponds including both ponds where egg masses were found and those where egg masses were not found. A CANLAB portable pH meter model was used to measure the 250-ml samples taken in plastic bottles. Samples were analyzed within 48 hrs. of collection. The samples were taken from the locations where spotted salamander habitat circles were measured, pH measurements were taken every 7-10 days while there were live eggs. The number of salamander egg masses in the habitat circle were then used in a regression analysis with the pH measurement in the ponds.

For spring peepers, pH measurements were taken at the sites where spring peepers were heard calling and sites of potential habitat. A sample per 100-m^2 was taken biweekly during the spring peeper calling season. All measurements from the sites were averaged to give a single pH measurement for that site. The pH samples were collected and analyzed in a similar manner as for those taken in the spotted salamander. Since it was not possible to measure pH in all habitat circles another method was used to determine breeding habitat. An estimate of the quality of the habitat for breeding for spring peepers was made by determining the maximum number of calling males during any one census. This number was then divided by the area within a line enclosing all points where a male was heard calling. This gave an estimate of density of calling males. Density was used rather than the total number to reduce any effect of the size of the habitat. This measure of spring peeper density was then used in a union regression analysis with the mean pH (Dixon 1975).

11.4 RESULTS AND DISCUSSION

11.4.1 SPOTTED SALAMANDERS

Spotted salamander egg masses were most frequently found in ditches along cottage roads. This was unexpected as it was initially predicted that habitat disturbance would remove much of the habitat required for breeding. Logs, ground vegetation cover, leaf litter, and rocks are usually removed around cottages and this is where adult salamanders are frequently found (Bishop 1941). The ditches along cottage roads were often filled with standing water created from the spring run-off. Most of the ditches contained refuse such as cans, bottles and paper, and organic debris was often abundant. By late May, the surface of the water was frequently covered with an oil slick created from run-off from the oil used to control dust on roads. Yet in one of these ditches, 62 egg masses were found. In contrast, pools of standing water in undeveloped lakes usually had clear waters with a thick layer of organic debris covering the bottom sediments. The maximum number of egg masses found in one of these pools was five. Overall there were 136 egg masses in standing water around the developed lakes compared to only nine around undeveloped lakes. Roads created 840 m^2 or 30 pools of standing water around developed lakes by disrupting drainage patterns compared to the 460 m^2 or 14 pools of standing water along undeveloped lakes. This difference in area alone, however, could not account for the higher total numbers of egg masses on developed lakes. The occurrence of the majority of egg masses in ditches along cottage roads resulted in a positive correlation between the density of egg masses and the development index (GDI). A linear regression

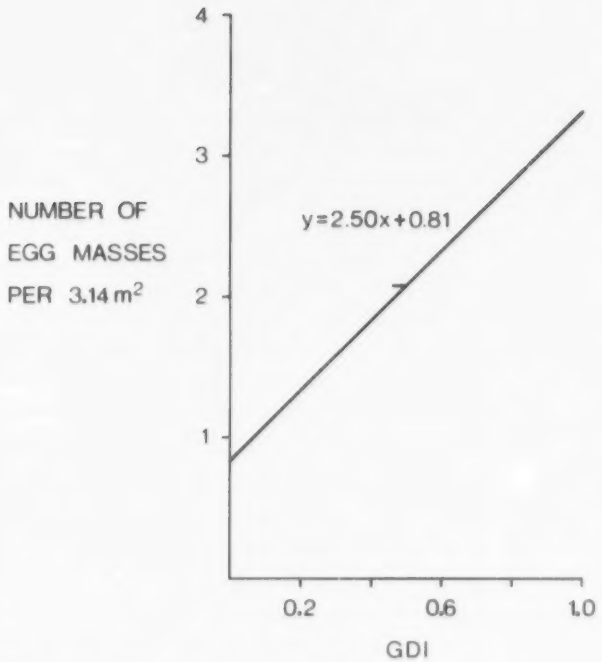

Figure 11.1 Linear regression of number of egg masses per 3.14 m^2 and the development index GDI.

was used to describe this relationship (Figure 11.1). GDI was significantly correlated with a number of habitat characteristics (Table 11.1). Linear regressions between GDI and the habitat characteristics showed that, in general, increasing habitat disturbance resulted in a reduction in the vegetation characteristics (Figure 11.2). The lack of an association of most of the ground layer characteristics with the development index is likely due to the maintenance practices along roads. The shrub and tree layers are usually removed but the ground layer is often left to grow because it does not hamper visibility for vehicles. The positive correlation between % water cover and QUADG reflects the greater area of standing water in more disturbed habitats. Since roads were usually 50 m from shore, the positive correlation between QUADG and the distance to shore is the result of the majority of the pools being along roads.

Table 11.1 Correlation coefficients for the density of salamander egg masses and the habitat variables and between QUADG and the habitat variables measured in salamander, spring peeper and turtle breeding sites.

Habitat Variable	Density of Spotted Salamander egg masses (n = 82)	GDI		
		Spotted Salamanders (n = 82)	Spring Peepers (n = 145)	Painted and Snapping Turtles (n = 107)
No. of shrub stems	-0.232*	-0.315*	-0.108	-0.174
No. of submerged species	-0.184	-0.0287*	-0.125	-
No. of ground species	-0.301*	-0.184	0.003	-0.289*
No. of shrub species	-0.345*	-0.350*	-0.092	-0.0274*
Submerged vegetation volume	-0.091	-0.014	-0.137	-
Ground vegetation volume	-0.326*	-0.185	-0.297*	-0.0348*
Shrub vegetation volume	-0.279*	-0.411*	-0.120	-0.246*
Tree vegetation volume	-0.072	-0.245*	0.045	-0.199*
Submerged deadwood volume	0.154	0.123	-0.095	-
Ground deadwood volume	-0.102	-0.133	-0.006	-0.302*
Shrub deadwood volume	-0.199	-0.271*	-0.013	-
Tree deadwood volume	-0.100	0.056	-0.073	-
Submerged vegetation cover	-0.120	0.006	-0.186	-
Ground vegetation cover	-0.343*	-0.309*	-0.245*	-0.264*
Shrub vegetation cover	-0.298*	-0.432*	-0.105	-0.215*
Tree vegetation cover	-0.105	-0.218*	0.017	-
Water cover	0.235*	0.334*	-0.210*	-
Percent coniferous composition - trees	-0.218*	-0.215*	0.032	-0.168
Percent coniferous composition - shrubs	-0.104	-0.127	0.075	-0.244*
Distance to shore	0.301*	0.396*	-0.102	0.316*
Water depth	0.001	-0.056	-0.219*	-
pH	0.227*	0.691*	-	-
GDI	0.309*	1.00	1.00	1.00

* $p < 0.05$

- indicates either not measured or the habitat variable was seldom 0.

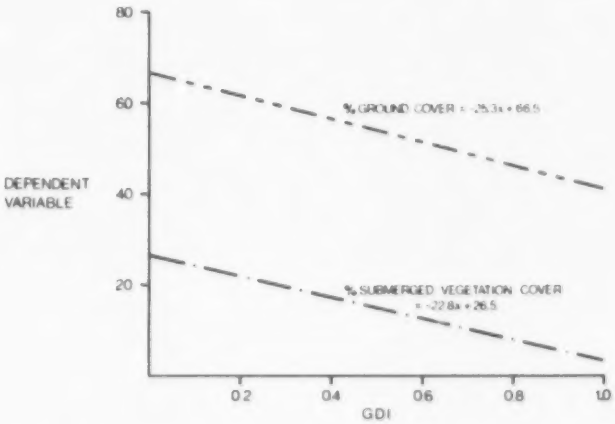

Figure 11.2 Linear regressions of habitat characteristics and the development index GDI.

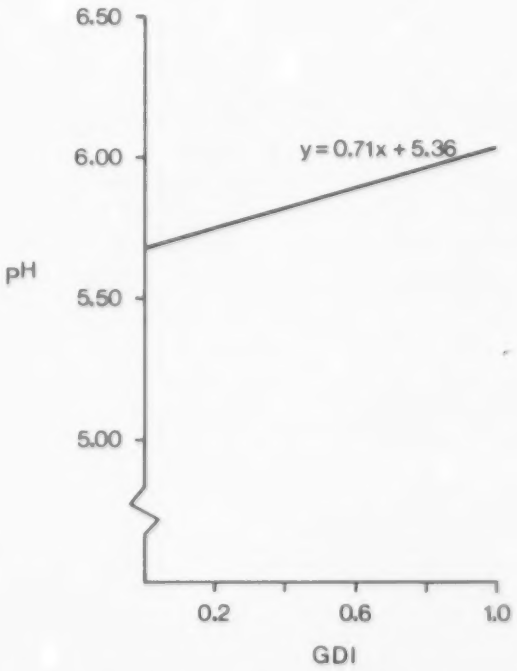

Figure 11.3 Linear regressions of pH and the development index GDI.

The variable with the highest correlation coefficient with GDI was pH. The regression between GDI and pH is shown in Figure 11.3. The increasing pH with disturbance is likely attributable to the close proximity of all disturbed ponds to roads. The sand and gravel used to build and maintain the roads would act as a renewable source of carbonates which would buffer the highly acidic precipitation and run-off which create the breeding ponds.

The majority of habitat characteristics with significant correlations with the density of egg masses were the same variables that were correlated with GDI. This indicates that GDI is a useful measure of the alteration of habitat characteristics which are associated with the occurrence of spotted salamander breeding habitat. Linear regressions were used to describe the relationship between the density of egg masses and the habitat characteristics (Figure 11.4 & 11.5).

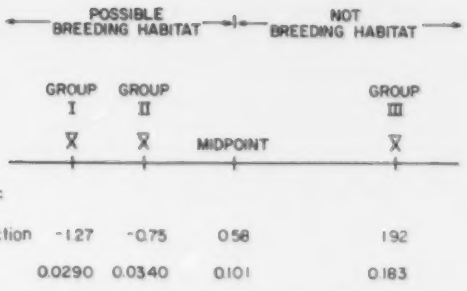

Figure 11.5 Linear decision scale (discriminant function) for not used, low density and high density of spring peeper male calling sites. DFA variable weightings were: substrate size, 0.561; number of shrub species, 0.454; ground coverage, −0.014; tree coverage, 0.022; distance to shore, −0.005; QUADG, 0.016. Sixty-eight percent were classified correctly.

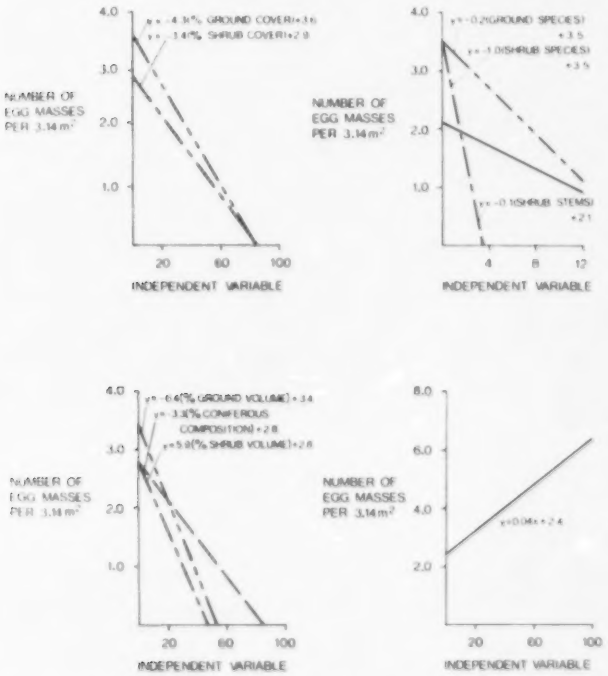
NUMBER OF EGG MASSES PER 3.14 m²
INDEPENDENT VARIABLE
NUMBER OF EGG MASSES PER 3.14 m²
INDEPENDENT VARIABLE
NUMBER OF EGG MASSES PER 3.14 m²
INDEPENDENT VARIABLE
NUMBER OF EGG MASSES PER 3.14 m²
INDEPENDENT VARIABLE

Figure 11.4 Linear regressions of habitat characteristics and the development index GDI.

The highest densities of egg masses were found in disturbed non-acidic standing water with little or no ground or shrub vegetation in deciduous habitats. These habitat characteristics describe the meadow and deciduous woodland temporary ponds and slow streams where spotted salamanders are known to breed in undisturbed areas (Bishop 1941; Pough and Wilson 1977). Pough and Wilson (1977) have noted that spotted salamanders do tend to be tolerant of land clearings. Bishop (1941) found egg masses in ditches along abandoned roads and railways.

Although there is an association between egg mass density and vegetational characteristics, these alone may not be the most important factors affecting salamander populations in this area. It is possible that a key environmental characteristic which is also associated with the habitat characteristics may have a direct effect upon egg hatchability and larva survival. The key environmental variable affecting salamander populations may be pH. The positive correlations between pH and GDI and also pH and egg mass density indicates that pH may be an important factor resulting in high densities in disturbed habitats. Salamanders will avoid acidic waters (Cooke and Fraser 1976; Pough and Wilson 1977; and Strijbosch 1979). Pough and Wilson (1977) hatched spotted salamander eggs in the laboratory and found that pH from 6.0 to 10.0 were tolerated but the greatest hatching success occurred at pH 7.0 to 9.0. In natural habitats, egg mortality was greater than 60 percent in ponds where pH was 6.0, whereas egg mortality was less than 1 percent in ponds where pH was near neutrality (Pough 1976). The egg masses of spotted salamanders are particularly vulnerable to acid stress because the eggs have little control in regulating their surrounding environment. The eggs are covered with hydrophilic gel which has a low buffering capacity and is in direct contact with the developing egg (Pough 1976). Eggs exposed to low pH are subject to cellular and subcellular rearrangements during development. Mortality occurs during different developmental stages but often during neurulation, late stages of gill development and at hatching. At pH 4.0 the perivitelline membrane shrinks and does not allow sufficient room for development and often the eggs do not hatch (Pough 1976; Pough and Wilson 1977).

The ponds used for breeding by spotted salamanders are particularly prone to acidification for several reasons. Most of the ponds are temporary and are filled by snow meltwater. These ponds collect from a limited drainage basin so there is little contact with soil buffer systems. Most of the precipitation which eventually fills the ponds, falls when the trees and shrubs are leafless so there is little chance for the vegetation to neutralize the rainfall (Pough and Wilson 1977). Pough and Wilson (1977) found that temporary ponds at Ithaca, New York had a mean pH of 4.5 compared to permanent ponds with a mean pH of 6.1. In our study, all of the breeding ponds were temporary and the mean pH was 5.75 with a range of 4.30 to 6.55.

Increased egg mortality in acidified ponds is probably an important environmental factor influencing the distribution of

spotted salamanders and subsequently the occurrence of egg masses in temporary ponds in central Ontario. The precipitation in the area has been acidified for at least the last 25 years (Cogbill 1976). Over this time, the population would have been subjected to sufficient mortality to reduce the numbers breeding in areas where pH has been depressed.

In conclusion, spotted salamanders benefit from the habitat disturbances associated with cottage development in central Ontario. The benefits are due to the creation of more potential habitat (i.e. non-acidic standing water in ditches along roads), to the alteration of the vegetation and to reduced acidity in the breeding pools. The effect of pH being both a strong determinant of egg hatching success and being highly correlated with habitat disturbance may confound any beneficial effects of vegetation disturbance. The strong positive correlation with development may, therefore, be due mainly to the influence of pH. The association of spotted salamander egg masses with increasing development may be quite different in habitats where precipitation does not have the heavy acid loading or the soil has better buffering capacity.

11.4.2 SPRING PEEPERS

The maximum number of spring peepers calling on developed lakes was only 226 compared with 443 on undeveloped lakes. It was not surprising that GDI was selected in the stepwise three-group DFA for not-used, low density and high density male calling sites (Figure 11.6). The locations of the group means on the discriminant function axis indicate that the high density calling sites are further separated from the not-used sites than are the low density sites. High density sites are associated with: small substrate size indicative of marsh habitats which frequently occurred at inflows and outflows; few shrub species characteristic of the homogeneous leatherleaf *(Chamaedaphne calyculata)* or sweet gale *(Myrica gale)* in marsh habitats; extensive ground coverage provided mainly by the leatherleaf and sweet gale which is used for perching sites for calling males; sparse tree cover which improves sound transmission (Fellers 1979); distance from shore; and little habitat disturbance in the ground layer. These habitat characteristics are similar to the field and open habitats described by Gerhardt (1973) for spring peeper calling sites in Georgia.

One difference in habitat of spring peepers breeding on developed and on undeveloped lakes which is not included in the DFA is the location of the breeding sites. On developed lakes, most of the spring peeper breeding sites were emergent vegetation especially at marshy areas at inflows and outflows. On developed lakes, most of the shoreline vegetation is removed to allow cottagers easy access to the water. Spring peeper breeding habitats on these lakes usually occurred in marshy areas back from shore created by disturbance of drainage patterns by cottages or roads. These disturbed sites were located where the first frogs were heard calling at the beginning of the breeding season. Spring peeper calling is dependent upon water temperature (Brown and Brown 1977) and these shallow waters warmed up quickly in the spring. Later, as the lake littoral zone temperature rose and much of the backshore standing water dried up, the lake marshes had the highest spring peeper numbers and there was little spring peeper activity on the developed lakes.

Correlation coefficients were computed to determine which habitat characteristics were associated with GDI (Table 11.1). Linear regressions were used to describe the relationships between GDI and the habitat characteristics (Figure 11.7). The occurrence of spring peepers in open habitats and the use of this fact as one of the selection criteria for unsuitable habitat resulted in little deviation in the shrub and tree characteristics from zero. Therefore, in this analysis, disturbance of spring peeper habitat was not associated with any tree or shrub characteristics but was associated with ground vegetation characteristics. The removal of the shoreline vegetation by cottages would account for the negative correlations of ground coverage, ground volume, and submerged vegetation cover with GDI. The negative correlations of water coverage and water depth with GDI are indicative of the reduced habitat disturbance in more extensive marshes. In large marshes, the spring peepers were usually calling far from shore and consequently in deeper water. Large marshes on developed lakes are one of the last areas of shoreline to be disturbed because of the greater economic costs of building cottages in these areas.

The habitat disturbance associated with each group can be estimated by the GDI group mean (Figure 11.6). The low GDI

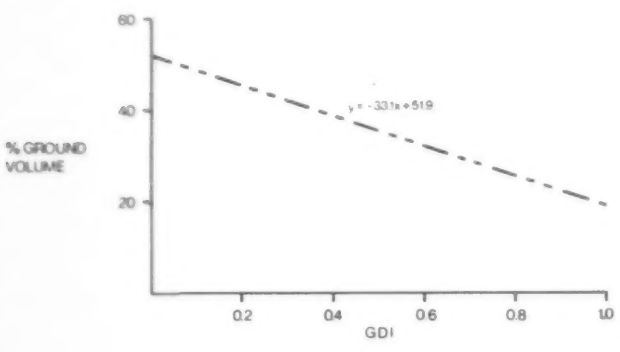

Figure 11.6 Linear regressions of habitat characteristics and the development index GDI.

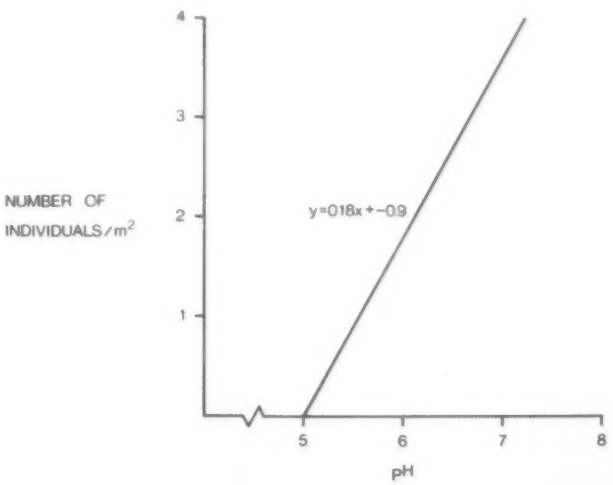

Figure 11.7 Linear regressions between the density of calling spring peeper males and mean pH ($r = 0.36$, $n = 35$, $p < 0.05$).

values for low and high density spring peeper calling sites (both 0.03) indicate that spring peepers are intolerant of even low levels of habitat disturbance. An approximation of the GDI cutpoint between potential and unsuitable habitat which is the midpoint between these two group means equals 0.10. This indicates that there is less than a 50% chance that a spring peeper would be found in habitats with greater than 10% of the ground layer disturbed. The inflexibility of spring peepers to utilize disturbed habitats for calling can likely be attributed to the restricted environmental conditions required in the males' calling sites. Females mate with males and then lay eggs in close proximity to the male calling site. The calling site must not only be suitable for perching and sound transmission but it must also be in close proximity to an area with adequate environmental conditions for egg and larvae survival. The removal of the ground layer in disturbed habitats would alter the structural, chemical, thermal, and biological characteristics of this vegetation layer. In most instances these changes must be too drastic for the spring peepers to adapt to these disturbed habitats.

To establish whether a particular section of habitat is potentially suitable as spring peeper breeding habitat, it must first meet the criteria of having emergent vegetation and/or be within 2 m of the lakeshore. Second, by computing the discriminant function score, its position along the discriminant function axis must be determined. Assuming the midpoint as the cut-off point between low density and not-used habitat, a habitat can be classed as potential (high or low density) or not-used spring peeper breeding habitat.

A significant positive relationship was found between the density of calling males and mean pH (Figure 11.7). Other studies have shown that pH affects the distribution, in different habitats, of larval anurans (Gosner and Black 1957; Cooke and Fraser 1976; Saber and Dunson 1978; Stsrijbosch 1979). Egg development, hatching, and tadpole survival are all affected by pH (Gosner and Black 1957; Saber and Dunson 1978). The causes of embryonic mortality are similar to those for salamanders. Developmental abnormalities occur and shrinkage of the priviteline membrane inhibits hatching of the egg (Gosner and Black 1957). In a laboratory study by Gosner and Black (1957) a pH of 3.8 resulted in complete mortality of spring peeper embryos and a pH of 4.2 caused at least 50 percent mortality. In our study areas, the range of pH was 4.35 to 6.20. The breeding sites at stream inflows or outflows, or along the lake littoral zone are subjected to particularly heavy acid loadings. During the spring run-off the acidic melt-water is usually at 0°C compared to the less acidic lake water at 4°C. The less dense colder water covers the lake surface including the littoral zone and empties through the outflows often with little mixing. The inflows are also acidic because much of the meltwater has had little opportunity to be diluted or buffered (Jefferies et al. 1979). At any one site pH fluctuated greatly and was lowest immediately after a heavy rainfall. One important stimulus for spring peeper calling is a rainfall so females were laying eggs when pH was lowest. Even though the pH usually rose during a dry period as it was subjected to some buffering and mixing, the critical period for egg development is during the early stages. Later developmental stages are more resistant to any detrimental effects caused by low pH (Gosner and Black 1957).

To establish whether disturbance of the spring peeper habitat had a similar effect on pH as in spotted salamander habitats, GDI was measured for each spring peeper calling area (measured as the total area in the ground layer disturbed/the total area) and used to compute a correlation coefficient with QUADG. The correlation coefficient, however, was not significant ($r = 0.177$, $p < 0.05$). This was attributed to calling areas seldom being near roads which could supply a source of calcium carbonates to buffer the rainfall.

In conclusion, there is strong evidence that the spring peeper population in central Ontario is being reduced by the detrimental effects of both habitat alteration associated with cottage development, and the reduced pH in breeding habitats caused by acidic precipitation. Other frog species which breed in the same habitats may also be experiencing reduced survival due to these environmental perturbations.

11.4.3 TURTLES

There were only 56 turtle diggings along developed lakes compared to 110 in an equal area along undeveloped lakes ($x^2 = 17.60$, df = 1, $p < 0.001$). Since lakes were selected to be similar in all characteristics except the degree of habitat disturbance, some aspect of cottage development must be influencing turtle digging sites on disturbed lakes.

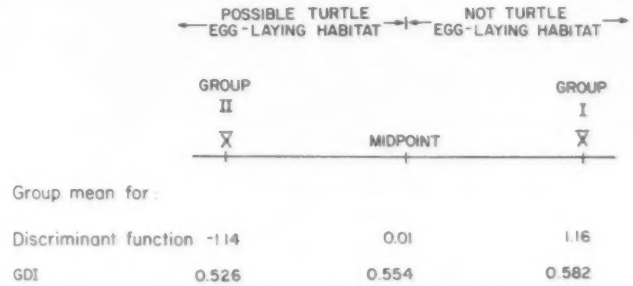

Figure 11.8 Linear decision scale (discriminant function) for turtle breeding sites. DFA variable weightings were: GDI, 0.013; earth coverage (%), −0.045; rock coverage, −0.045. Eighty-seven percent were classified correctly.

In a step-wise two-group discriminant function analysis between nest sites and not-used sites, GDI, percent bare earth cover and percent rock cover were selected as the variables which described a significant amount of the variance between the two groups (Figure 11.8). Nest sites were associated with less habitat disturbance than not-used sites. The linear regressions used to describe the GDI habitat characteristics (Figure 11.9) are similar to those for spotted salamander habitats. In general the removal of vegetation through disturbance leads to reduced foliage coverage and volume.

Since less than 75 percent tree and shrub cover were the criteria used for selecting the not-used turtle digging sites, there was this additional removal of vegetation associated with cottage development not measured in the QUADG habitat characteristic linear regressions. This additional habitat disturbance resulted in 2.2 ha with less than 75 percent tree and shrub cover on developed lakes compared to 0.3 ha on undeveloped lakes. The linear regressions between tree and

shrub characteristics and GDI, therefore, have a maximum value of 25 percent tree and shrub cover. This in part would explain why it would appear that if turtle digging sites are associated with low GDI values, the QUADG habitat characteristic regressions indicate they should also be associated with low foliage cover and volume. The maximum shrub and cover would only be 25 percent. Turtle digging sites were therefore associated with relatively open habitats. Nesting sites were found in open habitats for several reasons. Roots of plants can penetrate eggs and kill the developing embryo. Dense vegetation will shade and cool buried eggs which would slow development of the embryos. Vegetation also makes it more difficult for the female to bury the eggs.

The negative correlation between GDI and percent conifer composition of shrubs is indicative of cottager preferences for white birch *(Betula papyrifera)* and the removal of most coniferous shrubs such as hemlock *(Tsuga canadensis)*, and balsam fir *(Abies balsamea)*.

The positive correlation between GDI and distance to shore was the result of roads, which comprised a large proportion of disturbed not-used sites being on average 40 to 50 m from shore. Fifty metres was the maximum distance from shore which was sampled. Roads were also the sites with the maximum percentage of bare earth and were some of the most disturbed habitats. This would account for the positive correlation between GDI and bare earth. This result seems contradictory to the two-group DFA since the discriminant function describes a habitat with a high percent bare earth for turtle digging sites and from the linear regressions the low GDI value associated with turtle digging sites implies little bare earth. The discriminant function, however, must be interpreted with respect to all of the variables contributing to it. The DFA indicates, therefore, that turtle digging sites are associated with low QUADG plus a large area of bare earth and bare rock.

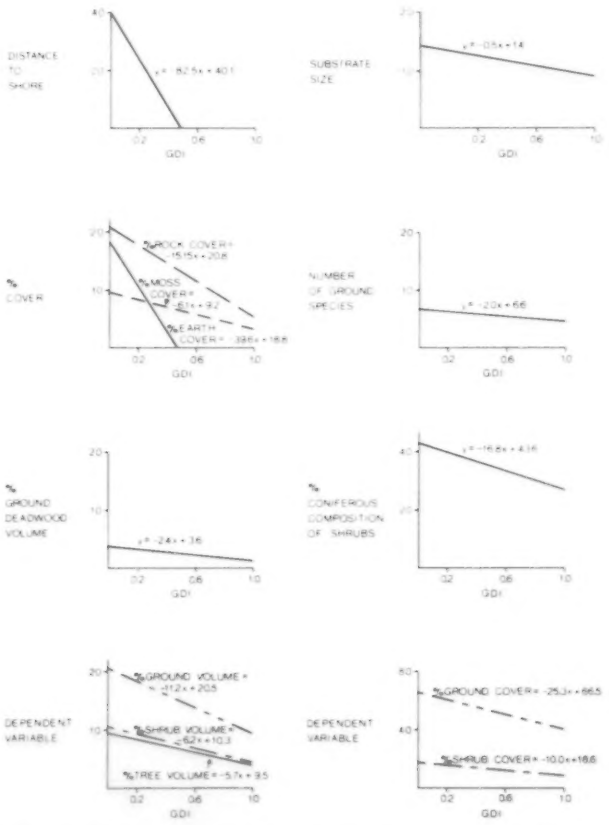

Figure 11.9 Linear regression of habitat characteristics and the development index GDI.

Bare rock was negatively correlated with GDI as a result of man-made structures (e.g. cottages, roads) and fill for lawns and gardens covering exposed bedrock. Turtle digging sites were associated with a large area of bare rock (as indicated by the DFA and GDI bare earth regression) because of the occurrence of shallow soils, with little vegetation in areas where shield bedrock was exposed. On undeveloped lakes, shield outcrops were the only areas where there was little vegetation and loose sandy soils. These were the areas most frequently used as egg-laying sites.

Another important component of GDI affecting turtles may be the measurement of human activity associated with development. The assumption must be made that more disturbed habitats are associated with greater human activity. This is probably a fair assumption since extensively cleared areas are usually used for human activities, such as lawns and roads, whereas areas with slight vegetation removal usually occur along roads and cottage clearings created mainly for greater visibility or visual aesthetics. Human activities will affect survival of adult turtles, eggs and hatchlings in several ways. Females en route to a nesting site and hatchlings when returning to the water may be killed on roads. Females may be interrupted during laying by vehicles or people and leave before completing the clutch and/or burying the eggs. The grading, oiling and maintenance of roads would greatly reduce survival of eggs and hatchlings in nests on roads and road edges. Nests in sandy beaches would be subjected to trampling, excavation and alteration of sand depth.

There is some evidence that egg-laying sites may be a limiting factor for turtle populations (Bayless 1975; Lonck and Obbard 1977). Along the undisturbed habitats we sampled, there was a limited amount of open habitat with sandy soils on undisturbed lakes and almost all that was available was used for turtle nesting. If nest sites along lakes are disturbed by cottage development, turtles may be forced to travel further from the lakes to find nesting sites. Energetic costs for both females and hatchlings would be higher as the distance travelled to the lake increased. Hatchlings would be exposed to terrestrial predators for a longer period of time. On developed lakes both females and hatchlings would be exposed to greater human disturbance. If turtles are forced to travel far from the lakes, they are more likely to cross roads where there is often high mortality caused by cars and trucks (Campbell 1973).

An indirect effect of cottage development on turtle populations is the increase in predator pressure in developed areas. Predators destroy a high proportion of nests. Up to 75 percent nest predation for snapping turtles has been reported (Hammer 1969). The main egg predators are skunks *(Mephitis mephitis)* and raccoons *(Procyon lotor)* and the populations of both of these species usually increase around disturbed habitats.

The mean GDI for turtle egg-laying habitat was 0.52. Suitable egg-laying sites were distinguished from unsuitable sites by

the DFA as having values of GDI less than 0.55. This is a relatively high level of disturbance which is tolerated by turtles. These values, however, describe a turtle digging site and do not reflect hatching success. Both snapping and painted turtles can live to be 15 to 20 years old (Gibbons 1968; Hammer 1969). Females may be still nesting on lakes where development has recently occurred but may now have reduced nesting success resulting in low recruitment. If nesting success is sufficiently reduced, the turtle populations will eventually decline on these developed lakes. To help maintain snapping and painted turtles on lakes, egg-laying sites should be left undisturbed wherever possible, particularly larger, frequently used sites. These areas can easily be identified by the shallow soil on exposed bedrock with open canopy.

It would also be beneficial to determine the nesting success of turtles on developed and undeveloped habitats as a function of both human activity and predator pressure. Turtle populations may also be influenced by the disturbance of basking sites, although the importance of alteration of these sites is not known.

11.5 ACKNOWLEDGEMENTS

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12. THE IMPORTANCE OF pH AND HABITAT DISTURBANCE IN AMPHIBIAN DISTRIBUTION IN CENTRAL ONTARIO

K. CLARK and D. EULER

12.1 SUMMARY

The distribution of 12 amphibian species was investigated relative to water chemistry variables, habitat measurement and an index which measured the amount of habitat disturbance caused by cottage development. Amphibians were censused at 20 streams and 21 ephemeral meltwater ponds in Haliburton and Muskoka districts in central Ontario. Principal component analysis and discriminant function analysis were used to determine the variables important in describing the distribution of each species.

Both pH and habitat disturbance were important in describing the distributions of a number of amphibian species. Bullfrogs *(Rana catesbeiana)* and spring peepers *(Hyla crucifer)* had high densities in non-acidic ponds and were more common where there was greater habitat disturbance. Wood frogs *(Rana sylvatica)* had low densities along acidic streams. Wood frogs, green frogs *(Rana clamitans)*, American toads *(Bufo americanus)* and red-backed salamanders *(Plethodon cinereus)* had low densities in streams with habitat disturbance. With increasing cottage development, and acidification of streams and ponds due to acid precipitation some amphibian species populations may be declining in central Ontario.

12.2 INTRODUCTION

Amphibians in central Ontario are presently being subjected to several environmental perturbations. Acidification of their habitat by acid precipitation and habitat disturbance caused by cottage development are two important concerns.

Population size and distribution of amphibians have both been correlated with pH in several habitats (Gosner and Black 1957; Mushinski and Brodie 1975; Cooke and Fraser 1976; Saber and Dunson 1978; Strijbosch 1979). In Sweden acidification of Lake Tranevatten has led to the extirpation of the common frog *(Rana temporaria)*, and the common toad *(Bufo bufo)* has become very rare (Hagstrom 1980). With the acidification of lakes and streams in Muskoka-Haliburton (Dillon et al. 1978), it is likely that amphibian distribution and abundance are being altered.

Reduced pH could lead to a reduction in amphibian food resources as invertebrate biomass can decrease and species composition can be altered (Hultberg and Grann 1975; Hendrey and Wright 1975; Abrahamsen et al. 1976). Another indirect effect of acidification is caused through shifts in predator pressure as fish are eliminated and invertebrate predator composition altered (Hagstrom 1980). In Sweden where fish populations have been eliminated, smooth newt *(Triturus vulgaris)* populations have substantially increased (Ibid).

Over the last several years hundreds of cottages have been built along lakes in central Ontario. Vegetation disturbance from this activity may also alter amphibian habitat. Habitat disturbance, associated with urban areas in Britain reduced the population size of 5 amphibian species (Beebe 1979). Disturbance of drainage patterns causes increased scouring and erosion of soils and protective cover along stream banks. This has reduced or eliminated the dusky salamander *(Desmognathus desmognathus)* from many disturbed areas (Orser and Shure 1972).

The purpose of this study was three fold: 1) to determine if relationships exist among the distribution of amphibian, vegetation, and water chemistry of aquatic habitats in central Ontario, 2) to determine the relationships between habitat disturbance and water chemistry of ponds and small streams, and 3) to assess the impact of cottage development on the distribution of amphibian populations.

12.3 METHODS

Twenty study plots were selected along streams sampled by Dillon et al. (1978), which represented a range of water chemistry characteristics and vegetation types. Cottage development varied from none to the highest observed in the study area. Each plot ran from the mouth of the stream, 50 m inland and included a 20 m strip of watershed centered on the stream.

Twenty-one ephemeral meltwater ponds within 50 m of the shoreline of eight lakes were selected to represent a range of habitats, water chemistry characteristics, and cottage development. Most of the ponds in disturbed habitats were along roads in ditches caused by alteration of drainage patterns. The pond study plots included the pond plus a 10 m strip of land around it.

Habitat disturbance was measured in each plot using a Ground Disturbance Index (Racey and Euler 1981). The index was calculated as follows:

$$GDI = (Ag)/Area$$

where Ag = the area disturbed in the ground layer.
Area = area of the plot.

An area was considered disturbed if a building or other man-made object occupied it, or if human activity had halted

natural succession and/or returned the area to an earlier successional stage.

Amphibians were counted in the ponds and streams every 10 to 14 days between 15 May and 30 July 1980 between 0800 and 1800. The species, and size class (for the bullfrog and the green frog *Rana clamitans*) small (2-3 cm), medium (3-5 cm), and large (5 cm) were recorded. Calling males were counted at night every two weeks during May and early June between 1800 and 2400. In late June and July, during the breeding season calling males were counted between 2400 and 0300. Red-backed salamander (*Plethodon cinereus*) adult populations were counted in early June. Egg masses of the spotted salamander (*Ambystoma maculatum*) were counted in the ponds between 30 April and 15 June, 1980.

Amphibian density was computed as the total number seen at a plot during all censuses divided by the number of censuses and then divided by the area of aquatic habitat for all species, except for wood frogs (*Rana sylvatica*), American toads (*Bufo americanus*) and spotted salamanders where the area terrestrial habitat was used.

Spotted salamander egg mass density was measured as the number of egg masses divided by the area of aquatic habitat. Vegetation types were mapped for each study area, and were described by the dominant plant species.

Habitat characteristics were also measured in each plot for the aquatic (submerged), ground (0-1 m), shrub (1-9 m) and tree (>9 m) layers. Vegetation cover and volume were measured at 10 randomly located 1-m^2 quadrats. Vegetation cover was estimated as the percent area of the ground which was covered by foliage. All trees and shrubs were counted as well as the number of plant species occurring in each layer.

To obtain detailed information about the habitat with which each amphibian species was associated, characteristics were also measured within 20 circles of 1 m radius (3.14 m^2) centered on positions where a species had been observed during at least two counts. The pH was also measured in these circles. A stepwise discriminant function analysis (DFA) was used with habitat characteristics measured in the 1-m^2 radius circles (BMD, Dixon 1975).

Water chemistry in streams was sampled weekly by staff from the Ontario Ministry of Environment. Colour, pH, conductivity, Fe, Ca, Na, K, alkalinity and acidity were measured. In ponds, weekly samples for pH, conductivity, Fe, Ca, alkalinity and acidity were taken. See Ontario Ministry of Environment (1975) for chemical sample preservation, bottle type and analysis. Measurements of pH were supplemented with samples taken at appromiately 20 m intervals along streams and one per 10 m^2 of pond area. These values were averaged to give a mean pH for each plot.

In order to determine the relationships among the amphibian species, habitat characteristics, and water chemistry variables, principal component analysis (PCA) was applied three times, using the amphibian density variables and each of the sets of environmental descriptors (Dixon 1975). Ponds and streams were analysed separately, as some species were associated only with either flowing or stationary water. The variables used in the PCA for ponds and streams were not always identical, because some variables were seldom greater than 0 in one of the habitats, but were important in others.

12.4 RESULTS

Both stream and pond plots on average had approximately a third of the ground layer disturbed although the plots ranged from none to complete vegetation disturbance (stream mean GDI = 29% and pond mean GDI = 37%) (Table 12.1). Water chemistry variables showed a wide range of values (Table 12.2).

Table 12.1. Mean and range of habitat characteristics for streams and ponds where various amphibian species were located.

Habitat Characteristic	Streams			Ponds		
	Mean	(s.d.)	Range	Mean	(s.d.)	Range
Ground disturbance index (%)	29	(31)	0-100	37	(34)	0-100
Conifer composition						
trees	30	(28)	0-94	12	(17)	0-50
shrubs	27	(29)	0-91	11	(16)	0-55
Vegetation volume						
aquatic (%)	11	(16)	0-65	20	(25)	0-76
ground (%)	32	(21)	5-82	26	(17)	9-84
shrub (%)	14	(8)	1-32	14	(11)	0-42
tree (%)	14	(12)	0-38	19	(17)	0-70
Conifer composition						
trees	30	(28)	0-94	12	(17)	0-50
shrubs	27	(29)	0-91	11	(16)	0-55
Vegetation volume						
aquatic (%)	11	(16)	0-65	20	(25)	0-76
ground (%)	32	(21)	5-82	26	(17)	9-84
shrub (%)	14	(8)	1-32	14	(11)	0-42
tree (%)	14	(12)	0-38	19	(17)	0-70
Vegetation cover						
aquatic (%)	21	(26)	0-86	29	(29)	0-88
ground (%)	58	(24)	9-100	46	(22)	2-99
shrub (%)	34	(18)	1-65	34	(23)	0-81
tree (%)	26	(23)	0-75	30	(26)	0-88
FHD	0.47	(0.16)	0.17-0.95	0.45	(15)	0.07-0.59
No. tree species	5	(2)	0-9	4	(3)	0-9
No. of trees/ha	200	(100)	0-500	290	(240)	0-900
No. of shrubs/ha	5000	(5000)	400-13500	5319	(3546)	866-14176

Table 12.2 Mean and range of water chemistry variables for streams and ponds where various amphibian species were located.

Variable	Streams			Ponds		
	Mean	(s.d.)	Range	Mean	(s.d.)	Range
pH	5.71	(0.56)	4.47-6.58	5.65	(0.46)	4.55-6.37
Colour (Hazen units)	49	(61)	0-214	*		-
Conductivity (μmhos cm^{-1})	31	(5)	25-40		(10)	6-51
Fe (mgL^{-1})	0.6	(0.8)	0.1-2.7	3.3	(2.3)	0.3-8.5
Ca (mgL^{-1})	2.8	(0.6)	2.0-4.8	3.4	(2.3)	1.7-6.6
Na (mgL^{-1})	0.8	(0.2)	0.0-1.2		-	-
K (mgL^{-1})	0.35	(0.11)	0.0-0.53		-	-
Cl (mgL^{-1})	0.43	(0.18)	0.0-0.90		-	-
Alkalinity (mgL^{-1} as $CaCo_3$)	2.0	(1.8)	0-6.0	5.2	(3.2)	0.4-12.2
Acidity (mgL^{-1} as $CaCo_3$)	6.9	(6.1)	0-21.5	14.2	(5.3)	4.6-23.0

* Not measured.

The green frog was the most common anuran in both ponds and streams (Table 12.3). The bullfrog was the second most

common and six other species occurred at much lower densities. Ponds supported higher densites of anurans (1311 individuals per ha) than streams (328 individuals per ha). There was little difference between the density of terrestrial anurans around ponds (10 individuals/ha) and streams (14 individuals/ha).

Table 12.3. Mean density per census of amphibian species from 20 ponds and 21 streams.

Amphibian Species		Mean Density animals/ha (S.D.) Ponds		Streams	
Green frog					
(Rana clamitans)	Total	889	(112)	224	(256)
	Small	219	(324)	84	(91)
	Large	670	(99)	140	(189)
Bullfrog					
(Rana catesbeiana)	Total	408	(822)	52	(76)
	Small	129	(290)	21	(47)
	Medium	209	(434)	16	(22)
	Large	70	(140)	15	(21)
Wood frog*					
(Rana sylvatica)		6	(7)	8	(8)
Spring peeper					
(Hyla crucifer)		2	(3)	0	(1)
American toad					
*(Bufo americanus)***		2	(4)	4	(5)
Chorus frog					
(Pseudacris triseriata)		4	(10)	0	(0)
Leopard frog					
(Rana pipiens)		4	(9)	23	(100)
Mink frog					
(Rana septentrionalis)		0	(0)	2	(6)
Tree frog					
(Hyla versicolor)		0	(0)	4	14
Pickeral frog					
(Rana palustris)		14	(54)	20	(68)
Red-backed salamander					
(Pletedon cinerus)†		2	(6)	2	(4)
TOTAL FROG DENSITY					
(individuals/ha)			1311		328

* Densities for these species were calculated per unit area of land since they were seldom seen in the water. All others per unit area of water

**These species were measured per ha of land since they were seldom seen in the water.

†These species were measured per ha of land since they were seldom seen in water.

Eight variables were selected in the stepwise DFA which accounted for a significant amount of the variance among species densities (Table 12.4). The absolute values of the standardized coefficients for each discriminant function axis indicates the relative contribution of each variable to each discriminant function axis. The number of plant species in the aquatic and ground layers were the major contributors to the first axis.

Percent ground vegetation volume, number of species in the aquatic and ground layers, Ground Disturbance Index, and pH were important determinants of the second discriminant function axis.

Table 12.4 Summary statistics for discriminant function analysis of habitat characteristics measured within 1-m radius of locations of frequent sightings of amphibians.

Variable*	Approx. F	Standardized Coefficients for discriminant function axes	
		I	II
Aquatic cover	23.69	−0.015	−0.006
% Ground vegetation volume	17.61	−0.007	−0.042
Ground Disturbance Index	15.02	−0.008	−0.013
No. aquatic species	13.13	−0.398	−0.038
No. ground species	11.68	−0.171	−0.020
% conifer composition shrubs	10.54	−0.005	−0.006
Mean pH	9.69	−0.004	−0.012
Dead wood aquatic volume	9.05	−0.028	−0.006

* Variables not entered: No. of shrubs, aquatic volume, shrub volume, tree volume, dead wood volume, ground cover, shrub cover, tree cover, % conifer composition of trees.

The mean discriminant function score for each species was plotted along the first two axes (Fig. 12.1). By interpreting the positions of each species along the axes, habitat associations of each species were described. Both small and medium bullfrogs, for example, were associated with disturbed aquatic habitats having low pH and many aquatic plant species, typical of small ponds, ditches and stream mouths. Large bullfrogs were associated with aquatic habitats having many submerged plants, higher pH, little disturbance, and some ground volume. Green frogs were found where shoreline aquatic habitats had some aquatic and ground species, moderate disturbance, and intermediate pH. Spotted

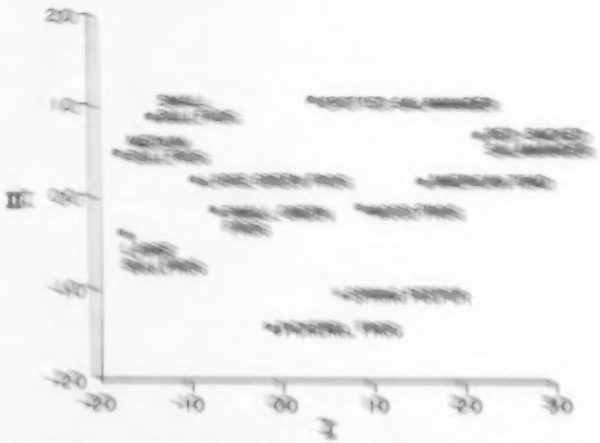

Figure 12.1 The mean discriminant function score of each species along the first two discriminant function axes for the analysis of habitat characteristics measured in 1 m radius circles at the location of 7 frequent sightings of each species. See text for interpretation of each axis.

salamander egg masses were associated with disturbed aquatic habitats with some ground species, high pH, and a low percent ground volume typical of small ponds and ditches along roads. The pickeral frog was associated with semi-aquatic, undisturbed habitats with many ground and few aquatic species, and considerable ground volume. The spring peeper was associated with more ground and fewer aquatic species typical of shoreline vegetation. The wood frog and American toad were associated with values indicative of terrestrial habitat with many ground species, some habitat disturbance, and intermediate pH. The red-backed salamander was also associated with terrestrial habitat, with many ground species, close to a low pH pond or stream and low ground volume.

PCA was applied using amphibian densities and habitat characteristics for ponds. The first principal component indicated that high densities of bullfrogs and spotted salamanders were associated with low foliage height diversity (FHD) indicative of a simple structure with little vegetation, or with vegetation in only one layer (Table 12.5). The second principal component described a gradient of increasing ground volume and decreasing FHD. High densities of green frogs had high values on this axis; wood frog densities and woodland habitats had low. The third component described a gradient that ranged from open ponds in mature forests or meadows where wood frog densities were high to ponds in immature forests where there were low wood frog densities.

Table 12.5. Sorted rotated factor loadings for the principal component analysis of amphibian densities and habitat characteristics in ponds.*

Variable	Principal Components I	II	III	IV
Bullfrog	0.935	0.0	0.0	0.0
Spotted salamander	0.896	0.0	0.0	0.0
Ground volume	0.0	0.821	0.0	0.0
Green frog	0.0	0.777	0.0	0.0
FHD**	-0.449	-0.655	0.0	0.0
Wood frog	-0.298	-0.535	-0.622	-0.265
No. shrub species	0.0	0.0	0.821	-0.328
No. of trees	0.0	0.0	0.788	0.0
Spring peeper	0.0	0.0	0.0	0.944
Disturbance Index	0.0	0.0	0.0	0.778
Shrub volume (%)	0.0	0.0	0.0	0.0
American toad	0.0	0.0	0.0	0.0
Aquatic volume (%)	0.0	0.0	0.0	0.0
No. of shrubs	0.0	0.0	0.0	0.0
Tree volume				
comp. vol. (%)	0.0	0.0	0.0	0.0
Variance explained (%)	23	18	15	15

* Loadings less than 0.250 have been replaced by 0.0
** MacArthur and MacArthur, 1961

For streams, the first principal component described a gradient of increasing shrub and tree volume, and tree density with which the number of green frogs had a weak, negative factor loading (Table 12.6). The second component described a gradient of decreasing habitat disturbance and number of shrub species, increasing conifer composition in the shrub layer, and increasing wood frog and toad densities. The third component was associated with increasing shrub density, ground volume, and green frog density and with decreasing conifer composition in the shrub layers and declining toad density.

Table 12.6. Sorted rotated factor loadings for the principal component analysis of amphibian densities and habitat characteristics in streams.*

Variable	Principal Components I	II	III	IV
Shrub volume	0.852	0.0	0.0	0.0
FHD	0.851	0.0	0.274	0.0
No. tree species	0.822	0.0	0.0	0.0
No. trees	0.809	0.0	0.0	0.0
Tree volume	0.800	0.0	0.0	0.0
Ground Disturbance Index	0.0	-0.890	0.0	0.0
Wood frog	0.0	0.715	0.0	0.0
American toad	0.0	0.664	-0.406	0.0
% conifer comp. shrubs	0.0	0.609	-0.532	0.267
No. shrub species	0.300	-0.800	0.0	0.0
No. of shrubs	0.0	0.0	0.822	0.0
Ground volume	0.0	0.0	0.697	0.0
Green frog	-0.319	0.0	0.622	0.0
Aquatic volume	0.0	0.0	0.0	0.898
Bullfrog	0.0	0.0	0.0	0.0
Spring peeper	0.0	0.0	0.0	0.0
Red-backed salamander	0.0	0.0	-0.255	0.0
% conifer comp. trees	0.0	0.0	-0.353	0.0
Variance explained (%)	24	18	11	11

* Loadings less than 0.250 have been replaced by 0.0

The PCA of frog densities and vegetation types used only variables with values greater than zero in at least five plots. This resulted in different sets of vegetation types in the pond and stream analyses. For ponds, the first principal component, with which spring peeper and spotted salamanders' egg masses were positively correlated, described a gradient of increasing pond, grass and sedge

Table 12.7. Sorted rotated factor loadings for the principal component analysis of amphibian densities and areas of vegetation types in ponds.

Variable	Principal Components I	II	III	IV
Algae	0.985	0.0	0.0	0.256
Pond	0.980	0.0	0.0	0.0
Spring peeper	0.980	0.0	0.0	0.0
Sphagnum	0.0	0.928	0.0	0.0
Bullfrog	0.0	0.920	0.0	0.0
Wood frog	0.0	-0.794	0.288	0.0
Sedge/ sensitive fern	0.0	-0.255	0.950	0.932
Moss	0.0	0.0	0.875	0.0
American toad	0.0	0.0	0.781	0.0
Trees	0.0	-0.259	0.632	-0.259
Road	0.327	0.0	0.0	0.881
Green frog	0.0	0.376	0.0	0.741
Herbaceous plants	0.0	0.0	0.0	0.0
Spotted salamander	0.407	0.276	0.0	0.0
Sweet gale or leatherleaf	0.0	0.0	0.0	0.0
Ground Disturbance Index	0.0	0.0	-0.309	0.0
Variance explained (%)	24	18	12	11

area, and to a less extent increasing road area (Table 12.7). High scores along this axis indicated large roadside ditches or ponds while small values were typical of small woodland ponds. The second component was associated with increasing bracken fern *(Pteridium aquilinum)* areas and decreasing royal *(Osmunda regalis)* and sensitive *(Onoclea sensibilis)* fern areas. It described a gradient with low scores in woodland marsh areas where wood frog densities were high and high scores with few wood frogs in more open drier areas where bracken fern was common. The third component was associated mainly with increasing tree and moss areas, decreasing habitat disturbance, and increasing toad and wood frog densities.

For streams, the first principal component was positively correlated with stream area, pickerelweed area, aquatic plant area, and bullfrog and spring peeper densities (Table 12.8). On the second component, toads, wood frogs, and red-backed salamanders had a high loading associated with little habitat disturbance, road area, and large area of trees. The third axis had a high positive loading for green frogs, sweet gale, leatherleaf, and raspberry areas.

Table 12.8. Sorted rotated factor loadings for the principal component analysis of amphibians densities and areas of vegetation types in streams.

Variable	Principal Components I	II	III	IV
Spring peeper	0.926	0.0	0.0	0.0
Bullfrog	0.903	0.0	0.0	0.0
Pickerelweed	0.864	0.0	0.0	0.0
Stream	0.719	0.0	0.0	0.0
Aquatic plants	0.528	0.0	0.0	0.0
American toad	0.0	0.826	0.0	0.0
Disturbance Index	-0.272	-0.749	0.0	0.0
Wood frog	0.0	0.683	0.0	0.501
Red-backed salamander	-0.257	0.627	-0.281	-0.362
Road	0.0	-0.567	0.0	0.0
Tree	0.339	0.549	-0.394	-0.506
Green frog	0.0	0.0	0.956	0.0
Sweet gale or leatherleaf	0.0	0.0	0.956	0.0
Raspberry	0.0	0.0	0.758	0.0
Sedge or grass	0.0	0.0	0.0	0.812
Alder or willow	0.0	0.0	0.0	0.734
Variance explained (%)	27	20	16	11

For the water chemistry variables and amphibian distribution in ponds, the first component had a high positive loading with spring peeper density, habitat disturbance, alkalinity, and pH (Table 12.9). On the second component, bullfrog and spotted salamander egg mass density had high positive loadings with conductivity. On the third component, wood frog density had positive loadings with increasing Ca concentration, and, to a lesser extent, with decreasing pH and conductivity.

For streams, where more water chemistry variables were used in the analysis, K, Na, Cl were negatively associated with Fe, and to a lesser degree, pH, bullfrog and toad densities (Table 12.10). On the second component, alkalinity, conductivity, pH, Ca concentration, and wood frog density had high positive loadings, while acidity and colour had

Table 12.9. Sorted rotated factor loadings for the principal component analysis of amphibian densities and water chemistry in ponds.

Variable	Prinicipal Components I	II	III	IV
Spring peeper	0.860	0.0	0.0	-0.251
Disturbance Index	0.756	0.0	0.0	0.0
Alkalinity	0.756	0.0	0.0	0.365
pH	0.747	0.0	-0.455	0.412
Bullfrog	0.612	0.938	0.0	0.0
Spotted salamander*	0.0	0.881	0.0	0.0
Conductivity	0.291	0.541	-0.377	-0.366
Wood frog	0.0	0.0	0.877	0.0
Ca	0.0	0.298	0.796	0.0
Fe	0.0	0.0	0.0	0.0
American toad	-0.323	0.0	0.0	0.828
Green frog	0.0	0.0	-0.261	0.0
Acidity	0.0	-0.290	0.0	0.0
Variance explained (%)	28	17	13	12

* egg mass density

negative loadings. The third component had positive loadings with disturbance and colour, and negative loadings with green frog and wood frog densities.

Table 12.10. Sorted rotated factor loadings for the principal component analysis of amphibian densities and water chemistry in streams.

Variable	Principal Components I	II	III	IV
K	0.908	0.0	0.0	0.0
Na	0.893	0.0	0.0	0.0
Cl	0.761	0.0	0.0	-0.285
Fe	-0.757	0.0	0.0	0.0
Bullfrog	-0.524	0.0	0.0	0.0
Alkalinity	0.0	0.863	0.0	0.0
Conductivity	0.0	0.812	0.0	0.0
pH	0.443	0.701	-0.380	0.0
Acidity	0.0	-0.556	0.0	-0.380
Ca	0.352	0.549	0.372	0.0
Colour	0.0	-0.548	0.782	0.0
Wood frog	-0.295	0.512	-0.485	0.0
Disturbance Index	0.0	0.0	0.859	0.0
Green frog	0.0	-0.348	-0.598	-0.581
Red-backed salamander	0.0	0.0	0.0	0.886
American toad	-0.442	0.0	-0.386	0.722
Road area	0.0	0.0	0.0	0.0
Spring peeper	0.0	0.0	0.0	0.0
Variance explained (%)	29	19	11	10

12.5 DISCUSSION

The Ground Disturbance Index and pH were negatively associated with a number of amphibian species densities, and were important variables in describing the distribution of most species. These associations, however, were generally different in ponds and streams. The positive associations of pH, alkalinity and the Ground Disturbance Index on the first principal component using water chemistry of ponds suggests disturbance along ponds may affect water chemistry. This is likely the result of the presence of disturbed ponds near roads. The main material used for road construction in this

area is crushed limestone, which is a source of $CaC0_3$ that acts as a buffering agent. Runoff from the road would increase alkalinity and pH.

The positive association of pH with density of spring peepers may be due to direct physiological stresses of low pH which cause embryonic mortality. In a laboratory study by Gosner and Black (1957), a pH of 3.8 resulted in total embryo mortality of spring peepers while a pH of 4.2 caused 50% mortality. Some of our study plots were as low as pH = 4.47. Spring peepers breed early during the spring runoff when the pH of pond and lake littoral zones is usually greatly depressed due to a surge of meltwater which has had little chance to be diluted or buffered (Jeffries et al. 1979).

In ponds, the positive loading of bullfrog density with alkalinity, pH, and conductivity, and the negative loading with royal and sensitive ferns, and FHD, indicates that high densities were found in more alkaline ponds in clearings. Bullfrogs are typically found along edges of ponds with submergent, aquatic vegetation (Cecil and Just 1979).

Spotted salamander egg masses were found only in ponds and intermittent streams. Egg mass density showed only weak loadings with vegetation types, and was positively associated with ground volume and conductivity. Spotted salamanders are tolerant of vegetation clearing which occurs in ditches along roads, railways, and woodland ponds and can utilize a wide range of habitats (Bishop 1941; Pough 1976; Pough and Wilson 1977). The association of high egg mass density with low ground volume is indicative of the open small ponds and ditches along roads where egg masses were common.

Wood frogs were positively correlated with Ca and negatively associated with pH and conductivity. Any toxic effects of pH are reduced at higher Ca levels for snails, small mussels and crustaceans (Okland and Okland 1980). Heavy metal toxicity, which may increase at low pH levels, is also reduced at high Ca levels (Christ and Pinko 1980). An explanation for the woodfrog's negative association with pH may be this decreased toxicity of low pH at high Ca concentrations.

Toad density was similar around ponds and streams. Adult toads, except during the breeding season in early May are mainly terrestrial and so are not dependent on aquatic habitats throughout most of the year. The weak associations with any chemical variables may reflect this independence. Toads were associated with relatively undisturbed woodland areas with extensive moss cover. Similarly, along streams, toad density was only weakly associated with water chemistry, and positively correlated with characteristics typical of undisturbed woodland habitats.

Red-backed salamanders were common along streams in undisturbed woodland areas. Neither water chemistry variables nor habitat characteristics were highly associated with their densities. This species is entirely terrestrial (Bishop 1941), and so water chemistry of a nearby stream may not be directly significant. The lack of association with any habitat characteristics may indicate a fair degree of plasticity of habitat use. The red-backed salamander utilizes a wide range of habitats, although other environmental variables such as soil moisture may be important in determining their distribution.

The green frog was the most common amphibian in all study areas. In the DFA small and large frogs showed little separation along the discriminant function axes. Martof (1953) noted that large green frogs select deep, clear waters, while smaller ones used more shallow areas. Since most of our study ponds were small and shallow, there may not have been the potential for this kind of separation. In the PCA for ponds, high densities of green frogs were associated with roads and a large volume of ground vegetation and low FHD, and were not associated with any vegetation types or water chemistry. Along streams, green frogs were most dense in uncoloured water with little disturbance, high shrub density and a large volume of ground vegetation. These habitat characteristics are also typical of large areas of swamps with leatherleaf, sweet gale, and raspberry. Coloured water has been associated with limited amphibian diversity (Leffingwell 1926; Gosner and Black 1957; Heatwole and Getz 1960). A high mortality rate of bullfrog larvae in coloured waters has been attributed to some intrinsic toxicity of dissolved organics (Saber and Dunson 1978). This kind of toxicity may account for the higher densities of greenfrogs in streams with little colour.

12.6 CONCLUSIONS

Amphibian species distributions were related to a number of habitat, vegetation type, and water chemistry variables. Two important variables were pH and the ground disturbance index. Spring peeper, bullfrog and wood frog densities were reduced in acidic plots. With the continuing occurrence of acidic preparation in central Ontario it is likely that these species populations may be declining.

The association of extensive habitat disturbance with low wood frog, American toad, green frog and red-backed salamander densities indicates that cottage development may also be reducing these species populations. The occurrence of high spring peeper and bull frog densities in disturbed ponds is likely due to the higher pH in ditches buffered with run-off from a nearby road although these disturbed habitats are not necessarily good quality amphibian habitats.

While this study did not measure actual population responses to environmental perturbations, it is clear that acidic precipitation and habitat disturbance are negatively affecting the animals studied. If habitats are lost, the populations will certainly decline. The length and timing will vary but the long-term trend is certainly down.

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